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Availability of Critical Scrap Metals Containing Chromium in the United States

Wrought Stainless Steels and Heat-Resisting Alloys

By Charles L. Kusik, Harry V. Makar, and Michel R. Mounier

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES
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AVAILABILITY OF CRITICAL SCRAP METALS CONTAINING CHROMIUM IN THE UNITED STATES

Wrought Stainless Steels and Heat-Resisting Alloys[1]

by

Charles L. Kusik,[2] Harry V. Makar,[3] and Michel R. Mounier[4]

ABSTRACT

As part of an effort to establish the extent of the domestic chromium supply that could be exploited in case of adverse changes in international chromium production and trading patterns, a two-part study was conducted for the Bureau of Mines, to assess the domestic availability of critical metals in scrap containing significant amounts of chromium. This report describes the part of the study that deals with wrought stainless steels and heat-resisting alloys. Data were collected on types of scrap, sources, quantities, and ultimate disposition, leading to the conclusion that in 1977 about 62,000 tons of contained chromium was unrecycled. Unrecovered obsolete stainless steel scrap accounts for most of these uncollected chromium values. Error margins in the amount of uncollected scrap are estimated to be 10 to 20 percent.

INTRODUCTION

Although world chromium resources are ample for the foreseeable future, political and economic events have raised doubts about the uninterrupted availability and reliability of chromium supplies. Chromium is used extensively in the metallurgical industry and has no technically viable substitute in such critical applications as the nickel-base superalloys required for aircraft gas turbine engines.

The United States is now almost totally dependent on foreign resources for its chromium mineral needs, although it does derive a portion of its metallic chromium supplies through recycling of scrap materials. A large quantity of chromium in alloy scrap, primarily stainless steel, is currently recycled annually. However, a large amount of chromium in scrap is not recycled domestically and hence is lost to the industry. Some of this scrap is downgraded into lower value applications where the chromium is either lost

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[1]This report was compiled and prepared by Arthur D. Little, Inc., Cambridge, Mass., under Bureau of Mines contract J0188170.
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[4]Project staff, Arthur D. Little, Inc., Cambridge, Mass.

in processing or could be replaced by less critical elements. Most chromium-bearing scrap is now recycled or refined to recover more valuable elements such as nickel, cobalt, and molybdenum, with chromium recovery only of secondary importance. The technology does not now exist to economically separate chromium from complex Ni-Fe-Cr alloys. Such a process would provide chromium values which could be used in times of national emergency. The Federal Emergency Management Agency (formerly Federal Preparedness Agency) sponsored this research through the Bureau of Mines, U.S. Department of the Interior, to develop such processes. The details of the research to develop such new processes will be described in separate reports at a future date.

This study was divided into two parts, each covering one of two broad alloy categories. Information Circular 8821 (3)[5] covers superalloys and cast heat- and corrosion-resisting alloys, and this publication covers wrought stainless steels and heat-resisting alloys. This division, although arbitrary, was convenient and justified because the respective alloy producers, end-use industries, and methods of recycling are rather distinct. Although large amounts of chromium are used in alloy steels and cast irons, these materials were not included in the survey; their chromium level is too lean to justify metal separation or recycling for their chromium content.

Thus, the studies upon which these reports are based are intended to provide an assessment of current U.S. commercial practices for recycling scrap containing significant concentrations of chromium. The domestic availability of wrought stainless steel and wrought heat-resisting alloy scrap is analyzed in this study. These materials are produced in high-volume production units by the specialty steel industry and are used in many sectors of our economy, ranging from appliances, automobiles, and architectural applications to energy conversion systems, petrochemical production, and aircraft structural parts. Information presented in the present report includes identification of the types of scrap, sources, quantities and ultimate disposition; for example, direct recycling, intermediate refining or disposal. In the methodology developed, chromium-containing metals are followed from the time they are shipped by alloy melters to the time they return as scrap. Data collected for the year 1977 and previous years are projected to the year 1990. Major losses are identified and estimated.

ACKNOWLEDGMENTS

The assistance of numerous individuals, companies, and organizations was invaluable in gathering and interpreting information and data for this study. While space limitations preclude giving credit to all who contributed, the authors wish to express their gratitude to the membership and staff of the following organizations for their cooperation and contributions: American Iron and Steel Institute, Washington, D.C.; Steel Service Center Institute, Cleveland, Ohio; Institute of Scrap Iron and Steel, Inc., Washington, D.C.; and the U.S. Department of Commerce.

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[5]Underlined numbers in parentheses refer to items in the list of references preceding the appendixes.

We are deeply indebted to Dr. Jack Westbrook and his colleagues of the Materials Information Service, General Electric Company, Schenectady, N.Y., for insights provided on scrap generation in fabrication operations.

Because of the many different domains of expertise relevant to this study, we wish to express our appreciation to numerous specialists within Arthur D. Little, Inc., for the insights provided to this program, and especially to Edward L. Pepper, Richard W. Hyde, Stanley V. Margolin, Frank M. Yans, and Edward R. Squibb. Special recognition is given to Louis Lee and Annette Nemetz for their computational assistance in developing background data.

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APPROACH

Overview

Scrap is continuously generated, whether there is a demand for it or not; it is an inherent byproduct of metal fabrication and also an inescapable consequence of wear, tear, and obsolescence of manufactured goods whether made of stainless steel or of other materials.

Scrap and other recycled materials, such as processed flue dust, grinding swarf, and skulls, are used by stainless steelmakers ("melters") along with virgin materials. Recyclers collect just enough scrap to meet demand. Thus, all scrap is not necessarily recycled. Purchased scrap has a much wider range of chemical composition than the intended products: alloy-free carbon steel is used to dilute the virgin materials, and superalloy scrap may provide such alloying elements as nickel, chromium, molybdenum, cobalt, and tungsten.

The average stainless steel mill melts considerably more scrap than virgin materials. Over 95 percent of wrought stainless and heat-resisting alloys is melted and partially refined in electric arc furnaces, followed by pouring into an argon-oxygen decarburization (AOD) vessel, where most refining and chemistry adjustment takes place. The AOD process, like the basic oxygen furnace (BOF) for steelmaking, is autogenous and is even sufficiently exothermic to allow for small additions of perfectly identified metallics such as home scrap. Further industry background is provided in appendix A.

To avoid confusion between finished products from steel mills (sheet, strip, bars, etc.) and finished products made in manufacturing and fabricating operations (automobiles, utensils, etc.), we have used the term "steel mill products" to apply to shipments from steel mills and the term "manufactured and fabricated products" to apply to products shipped to ultimate consumers.

Because prompt scrap generation rates differ depending on the product manufactured, a distinction is made between finished products from steel mills and semifinished products (billets, blooms, sheet bars, etc.) produced and shipped by steel mills.

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Recognizing that steel mill products are often classified as primary products, this designation has been avoided in order to eliminate confusion between products made in the primary industries (such as those based upon virgin materials) and secondary industries (such as those based upon scrap materials).

The term "scrap" is used to define stainless steel whenever it is no longer destined to serve a useful function in a product. Some of the scrap so generated may be collected; other such scrap may be uncollected or discarded. Thus, a distinction between scrap generated, scrap collected for recycling, and scrap that goes uncollected is made. The term "ton" throughout this report refers to a net (short) ton of 2,000 pounds.

Scrap generated within the steel mill complex, often referred to as "home scrap" or "run-around scrap," is not considered within the scope of this study. Scrap generated in fabricating operations or manufacturing operations is labeled here as "prompt industrial scrap" or simply "prompt scrap;" it is often referred to as "new scrap" in other studies. Scrap generated at the end of a product's useful life is referred to as "obsolete scrap;" in other studies it is frequently called postconsumer scrap, old scrap, or country scrap.

When referring to stainless steel, it is understood that the heat-resisting alloys are always included because this is often the way such data are reported; any errors introduced by such data aggregation would be small since heat-resisting alloys amount to less than 2 percent of the stainless steel shipments (1). The term "domestic shipments" as used in this study covers net shipments as reported by the American Iron and Steel Institute, which excludes intercompany shipments. Similarly, net imports are calculated by subtracting total exports from total imports of stainless steel mill products to the United States.

Generally, initially reported data are often shown to six or more significant figures. After any allocation or adjustments, figures are rounded off to the nearest thousand or hundred tons.

Industry Subsectors

Figure 1 illustrates the flow of stainless steel products and stainless steel scrap between producers and consumers. Major elements include

Blocks 1-2.--Stainless steel producers involved in steelmaking and steel forming. The domestic shipments of stainless steel include ingots, semifinished steel mill products (such as billets and sheet bars), and finished stainless steel mill products (such as sheet, strip, bars, wire and wire products). Home scrap recycled in the steel mill is not included in the scope of this work.

Block 3.--Steel service centers, which account for about 35 to 40 percent of the shipments made by domestic stainless steel producers.

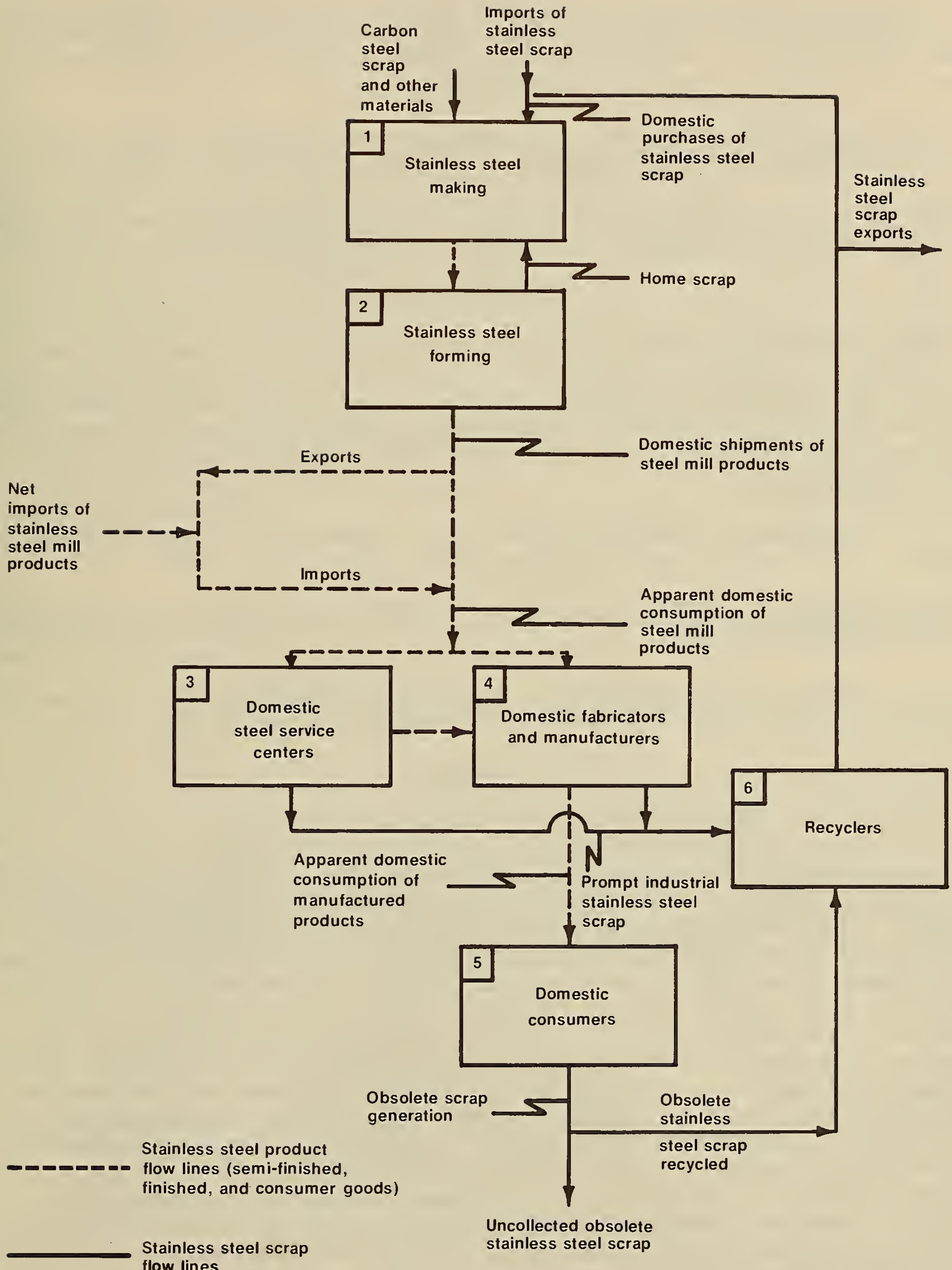


FIGURE 1. - Diagram illustrating flow of stainless steel products and stainless steel scrap between producers and consumers.

Block 4.--Domestic fabricators and manufacturers, which, like the domestic steel mill service centers, rely to some extent on imports of stainless steel mill products. Such imports have typically amounted to less than 10 percent of apparent domestic consumption.

Block 5.--Domestic consumers of stainless steel products made by fabricators and manufacturers of automobiles, appliances, utensils, etc.

Block 6.--Stainless steel recyclers, which collect prompt industrial and obsolete scrap for shipment to domestic consumers and for export.

Data Sources

Major published sources of data on stainless steel shipments include

1. Net domestic shipments of stainless steel mill products (bars, sheet, strip, wire, etc.), by market classification, as published by the American Iron and Steel Institute (AISI) in their Annual Statistical Report (1) and other publications.

2. Department of Commerce statistics on exports and imports (14) of stainless steel mill products by shape (bars, sheet, pipe, tube, etc.).

3. Shipments of stainless steel mill products by alloy type as published in Metal Statistics (2).

4. Bureau of Mines statistics on receipts of stainless steel scrap by consumers, largely stainless steel makers (13, May 1978, p. 15).

Methodology

Apparent Domestic Consumption Calculation

Data published by the American Iron and Steel Institute show domestic shipments of stainless steel (including heat-resisting alloys) by producers (1). Since obsolete stainless steel scrap could arise from products manufactured up to 20 or more years ago, statistics were collected on domestic shipments from 1950 to the base year, 1977. Such shipments by reporting members of AISI include exports. Domestic steel service centers are also involved in the export and import of stainless steel mill products which are reported by major mill product category by the Department of Commerce (14). Because net imports of stainless steel products, indicated by N in the following equations were not easily obtainable before 1964 and apparently were small based on discussions with industry personnel, net import calculations are based upon information and trend lines developed from 1964 to 1977. From such statistics net imports can be determined (total imports minus total exports). Apparent domestic consumption of stainless steel mill products (D) can then be derived by adding domestic shipments of stainless steel mill products to net imports (fig. 1).

Calculated details are provided in the next section entitled, "Apparent Domestic Consumption of Stainless Steel Mill Products."

Estimates of Prompt Industrial Stainless Steel Scrap

In fabricating and manufacturing operations, domestic consumers of stainless steel mill products generate prompt industrial scrap. Published data on prompt industrial stainless steel scrap generation appeared to be lacking. While Bureau of Mines data report on the receipt of stainless steel scrap, such data are not disaggregated into prompt industrial and obsolete scrap. As a result, the prompt industrial stainless steel scrap generation (G) was estimated based upon apparent domestic consumption of stainless steel mill products for the base year 1977. The amount of such scrap generated indomestic fabricating and manufacturing operations has been estimated by product shapes consumed (bar, sheet, pipe, etc.), with each shape having a characteristic yield (Y) and yield loss (1-Y). Such estimates of yield losses are based upon discussions with industry personnel.

Total prompt industrial scrap generation (G_{prompt}) can be expressed by the following equation:

$$G_{prompt} = D_{77}\ (1-Y_{av})_{77}, \qquad (1)$$

where $(1-Y_{av})_{77}$ is the average yield loss to scrap in manufacturing consumer goods from stainless steel mill products for 1977.

Estimates of Obsolete Scrap Generation

After a product's useful life, obsolete scrap is generated, as indicated in figure 1. Typically, stainless steel scrap so generated was fabricated from mill products produced many years earlier. The approach used in estimating obsolete scrap generation involved calculating apparent domestic consumption of stainless steel manufactured products (fig. 1). Statistics on domestic shipments were plotted from 1950 through 1977, and an equation was then developed by linear regression of this data (least squares fit) to represent domestic shipments by year. The form of this equation was

$$D_0 = A_0 + B_0 T \qquad (2)$$

where D_0 represents domestic shipments, A_0 and B_0 are constants, and T = year minus 1900; for example, T = 50, 59, 63, and 77 for the years 1950, 1959, 1963, and 1977, respectively. By plotting data on net imports over time, a similar equation was developed of the form

$$N = A' + B'T \qquad (3)$$

where N represents tons of net imports and A' and B' are constants. Typically, net imports have accounted for less than 10 percent of apparent domestic consumption.

By adding domestic shipments (D_0) to net imports (N), one obtains apparent domestic consumption of steel mill products (D):

$$D = (A_0 + A') + (B_0 + B')\ T \tag{4a}$$

$$D = A + BT \tag{4b}$$

where $A = A_0 + A'$ and $B = B_0 + B'$.

For any given year, apparent domestic consumption of stainless steel manufactured goods can now be calculated in a three-step process: (1) determining apparent domestic consumption of stainless steel mill products from equation 4b, (2) estimating yield losses to scrap ($D-Y_{av}D$) in converting steel mill products to manufactured goods, and (3) calculating stainless steel in manufactured goods (C_g) by subtracting yield losses to scrap calculated in step 2 from apparent domestic consumption of mill products found in step 1. As a result, in any year (j) apparent domestic consumption of consumer goods containing stainless steel (C_{gj}) can be expressed as follows:

$$C_{gj} = D_j - [(1-Y_{av})D]_j \tag{5a}$$

or

$$C_{gj} = (Y_{av}D)_j \tag{5b}$$

Market classifications were then used, as published by the American Iron and Steel Institute, to form a basis for estimating manufactured or fabricated product lives. Two approaches can be taken to estimate the product lives:

Approach A.--Estimating product lifetimes by market classification (automotive, appliances, utensils, cutlery, etc.) and then determining shipments of stainless steel products to this market sector in the year that the product was made. Thus, for an automobile with an average product life of about 10 years, we would determine the amount of stainless steel that was consumed in the manufacture of automobiles in 1967 to determine the amount of obsolete stainless steel scrap generated from automobiles in 1977. Such an approach would demand determining apparent domestic consumption of stainless steel manufactured or fabricated products by market classification for each year that such products were manufactured that showed up as obsolete scrap in 1977.

Approach B.--Classifying manufactured goods into two categories; namely, those with a short life expectancy of 10 ±5 years, and those with a long life expectancy of 20 ±5 years. One can then estimate the percent of manufactured goods made in each sector that either have a 10- or a 20-year life span. Using this approach, apparent domestic shipments and net imports of stainless steel fabricated products need be determined only for 1957 and 1967.

If the distribution of steel mill products shipped to each major market classification remains constant over time, either of the above two approaches would give essentially the same results, assuming a consistent set of data is

applied to the linear equations developed on apparent domestic consumption. That is, an estimate of a 15-year life for products in a given market classification would be equivalent to assuming that 50 percent of the products have a 10-year life and 50 percent of the products have a 20-year life on the average.

Except in a few instances, data on product lives by AISI market classification are extremely limited. Thus, there is little to recommend one approach over the other. As a result, approach B was chosen because (1) this approach reduced the number of calculations one had to perform on shipments by market sector by year, and (2) as better data become available on product lifetimes, it will be easier to update this study. The mix of short-term and long-term product lives used in a given market sector was largely based on judgments rendered by industry personnel. Where better information was readily available (for example, lives of automobiles), such data were used. Designating the average life in years of products using stainless steel to be L, the obsolete scrap generation rate (G_{obs}) in 1977 is given by apparent consumption of manufactured goods "L" years ago:

$$G_{obs} = C_{gt} \tag{6a}$$

$$= (Y_{av}D)_t \tag{6b}$$

where t = 1977-L (t is the average year in which goods were manufactured that are being discarded today).

Total scrap generation (G) is then obtained by adding equation 1 for prompt scrap to equation 6b for obsolete scrap, or

$$G = (D-Y_{av}D)_{77} + (Y_{av}D)_t \tag{7}$$

Scrap Generation Versus Collection

As indicated in figure 1, only a fraction of the scrap generated is collected and the remainder remains uncollected. Data are published monthly by the Bureau of Mines on stainless steel scrap receipts by melters (13). By neglecting inventory changes, receipts are assumed equal to consumption, S_o.

Scrap Imports and Exports

Although data on exports of stainless steel scrap in 1977 were available, there were no comparable statistics for the imports of stainless steel scrap. However, the U.S. Department of Commerce collects information on the total amount of ferrous scrap imported (14) and breaks down data on ferrous scrap on which import duties were and were not levied. Stainless steel scrap imports were estimated based upon these statistics and the judgments offered by scrap dealers and U.S. Department of Commerce officials. By adding estimated net scrap exports (S_E) to scrap consumption (S_o), we obtain total domestic collection of scrap (S):

$$S = S_o + S_E. \tag{8}$$

Estimates of Uncollected Stainless Steel Scrap

The quantity of uncollected stainless steel scrap in 1977 (U) is then estimated simply as the difference between scrap collected in 1977 (S_{77}) and scrap generated:

$$U = G_{prompt} + G_{obs} - S_{77} \tag{9a}$$

$$= (D-Y_{av}D)_{77} + (Y_{av}D)_t - S_{77} \tag{9b}$$

where $(D-Y_{av}D)_{77}$ = prompt scrap generation,

$(Y_{av}D)_t$ = obsolete scrap generation,

and S_{77} = scrap collection.

Based on discussions with recyclers, a preliminary assessment of the main sources of uncollected scrap was undertaken. This included a limited survey of opinion by recyclers and other scrap industry experts as to the percent of obsolete scrap generated that was actually collected. Major sources of potential error were then examined, and additional data needs were identified.

APPARENT DOMESTIC CONSUMPTION OF STAINLESS STEEL MILL PRODUCTS

Domestic Shipments

Ingots produced by stainless steel melters are subsequently formed into semifinished products such as slabs, billets, or, in some cases, blooms. Because of economies achieved, these semifinished shapes can be produced in an alternative fashion by continuous casting, which has rapidly gained acceptance over conventional ingot casting. Home scrap is generated as the semifinished products are rolled in steel mills into final shapes such as bars, rods, sheets, strips, or plates. Such scrap is also generated when semifinished or partially finished products are sent to nonintegrated finishing operations, such as strip rerollers, wire drawers, or specialized pipe and tube makers. Since such scrap is typically handled by recyclers, it is classified as prompt industrial scrap rather than as home scrap and thus is included in the scope of this study.

Since semifinished products have accounted for only about 5 percent of domestic stainless steel mill shipments, as reported by the AISI, the predominant and most important steel mill shipments are finished steel mill products. The finished and semifinished steel mill products are shipped by truck or rail to distributors (steel service centers), manufacturers, fabricators, or exporters.

In 1977, 1,860,000 tons of stainless and heat-resisting steels were poured, resulting in domestic shipments of 1,120,000 tons of finished products (1). Most of the difference--750,000 tons, or 40 percent of molten steel production--is home scrap; 676,000 tons of such scrap were melted in 1977. The difference is accounted for by slags, dusts, mill scale, and grinding

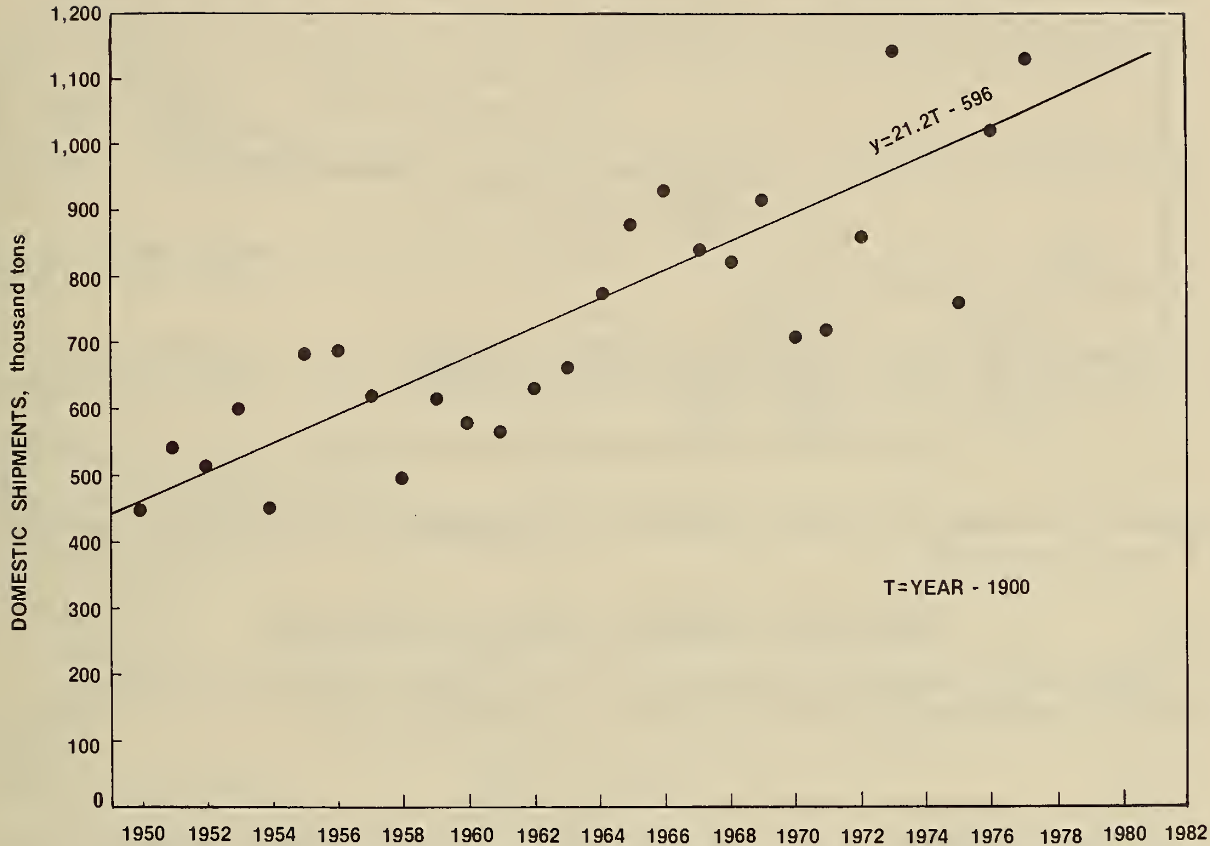


FIGURE 2. - Domestic shipments of stainless steel.

residues; some of these waste materials find their way back to the melting stage with or without intermediate treatment. Domestic shipments of stainless steel mill products as reported by the AISI (1) are plotted in figure 2 from 1950 through 1977. A "best line" through the data points determined by linear regression ("least squares fit") yields an equation of the form

$$D_o = 21.24\ T - 595.9, \tag{10}$$

where D_o = thousand tons of domestic stainless steel shipments and T = year minus 1900.

Net Imports

Figure 3 shows Department of Commerce data (14) on net imports of stainless steel mill products. Published information before 1964 was not readily available. A "best line" developed by linear regression ("least squares fit") through the data points yields the following equation:

$$N = 6.007\ T - 355.4 \tag{11}$$

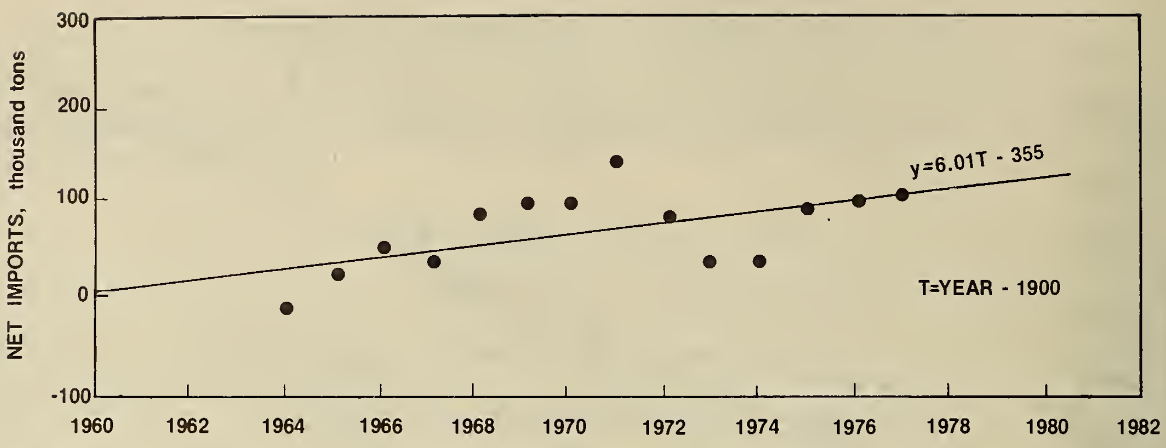


FIGURE 3. - Net imports of stainless steel.

where N = thousand tons of net imports of stainless steel mill products, and T = year minus 1900.

Equation for Apparent Domestic Consumption

Addition of domestic shipments (S) to net imports (N) gives apparent domestic consumption of stainless steel mill products (D):

$$D = 27.24\ T - 951.3 \tag{12}$$

Taking cognizance of the years over which the data support this equation, the relationship proves especially useful in calculations involving obsolete scrap generation. Apparent domestic consumption is used for estimating scrap generation, as discussed in the next section.

SCRAP GENERATION AND COLLECTION

Estimates of Scrap Generation

Prompt Industrial Scrap

In its Annual Statistical Report, the American Iron and Steel Institute (1) publishes net domestic shipments of stainless steel mill products (including heat-resistant alloys), as summarized in the first columns of table 1. Net imports derived from Department of Commerce data by major product category are then added to domestic shipments in table 1 to arrive at apparent domestic consumption of steel mill products.

The semifinished products are distributed to finished steel mill product categories using a 60-percent yield. This yield is based on an average value calculated from AISI data for 1977 (1) on net shipments of stainless steel mill products (1,120,000 tons in 1977) divided by production of 1,860,000 tons of raw steel (that is, the first solid state after melting, including ingots, strand or pressure-cast blooms, billets, slabs, or other product forms). The

difference, amounting to 40 percent of the weight of semifinished products shipped to processors other than steel mills, is assumed to be prompt industrial scrap. Thus, 33,900 tons of steel-mill-type finished products are produced from semifinished products (60 percent of 56.5), which simultaneously results in 22,600 tons of prompt industrial scrap being generated.

TABLE 1. - Apparent domestic consumption of stainless steel mill products in 1977

(Thousand tons)

Product	Domestic shipments[1]	Imports minus exports[2]	Apparent domestic consumption: Steel mill products, semifinished and finished[3]	Apparent domestic consumption: Finished products manufactured from semifinished[4]	Apparent domestic consumption: Finished products
Semifinished (ingots, steel castings, blooms, slabs, billets, sheet bars)	60.3	-3.8	56.5	NAp	NAp
Finished products:					
Wire products:					
Wire rod[5]	24.7				
Drawn wire	25.8	44.6	95.1	2.8	[6]97.9
Total	50.5				
Plates	85.8	[7]4.6	90.4	2.6	[6]93.0
Bars:					
Hot-rolled bars	37.8				
Cold-finished bars	86.8	21.8	146.4	4.2	[6]150.6
Total	124.6				
Pipes and tubes	32.3	15.1	47.4	1.4	[6]48.8
Sheet and strip:					
Hot-rolled sheet	22.6				
Cold-rolled sheet	474.4				
Hot-rolled strip	4.8	25.8	790.6	22.9	[6]813.5
Cold-rolled strip	263.0				
Total	764.8				
Grand total	1,118.3	108.1	1,226.4	33.9	1,203.8

NAp Not applicable.
[1]AISI Annual Statistical Report, 1977 (1).
[2]Steel Mill Products, U.S. Department of Commerce, Bureau of the Census, 1977 (as reported in reference 1).
[3]Apparent domestic consumption = shipments from U.S. mills plus imports minus exports.
[4]Calculated by allocating semifinished product category shipments to finished product categories in proportion to tonnage of finished products and assuming a 40 percent yield loss to scrap. The yield loss to scrap agrees with reported domestic shipments by AISI of 1,118,000 tons and crude steel production of 1,862,000 tons in 1977.
[5]AISI identifies wire rod as a semifinished product. For convenience in estimating prompt scrap generation, wire rod is classified with wire products in this study.
[6]Addition of prior 2 columns of finished products.
[7]Includes stainless steel structurals which are not reported separately.

The 33,900 tons were then allocated to finished-product categories in proportion to apparent domestic consumption of finished steel mill products. For example, in table 1, 2,600 of the 33,900 tons is allocated to plate category as follows: 33.9 (90.4)/(1,226.4 - 56.5) = 2.6. This is then added to the 90,400 tons of plates from domestic shipments and net imports to arrive at a calculated apparent domestic consumption of plates amounting to 93,000 tons. The results of the allocation calculations for the other product categories are also summarized in table 1, which shows total apparent consumption of steel mill finished products to be 1,203,800 tons in 1977. These finished-product categories and consumption tonnages are now used to calculate prompt industrial scrap generation.

The stainless steel mill products are consumed in turn by manufacturing operations that produce prompt industrial scrap. Since data on scrap generation from manufacturing operations were not readily available, prompt industrial scrap generation rates for stainless steel consumed were estimated by type of product (bar, sheet and strip, etc.) used in manufacturing operations. Table 2 shows stainless steel yield losses to scrap based on judgments or estimates made by manufacturers and other industry personnel. Based on these yield losses, table 2 also shows calculations on prompt industrial scrap generated. For example, a 15-percent yield loss to scrap applied to 97,900 tons of stainless steel plates consumed in manufacturing operations results in 14,000 tons of scrap, as shown in the last column of table 2.

TABLE 2. - Estimated stainless steel prompt scrap generation in 1977

(Thousand tons)

Stainless steel mill product	Apparent domestic consumption	Yield loss to scrap	Estimated prompt industrial scrap generated
Wire products and wire rod products......	97.9	10.0	9.8
Plates................................	93.0	15.0	14.0
Bars..................................	150.6	40.0	60.2
Pipe and tubing.......................	48.8	10.0	4.9
Sheet and strip.......................	813.5	12.5	101.7
Total.............................	NAp	NAp	190.6
Scrap generated outside of steel mills in producing finished products from semifinished (for example, ingots, blooms, billets)............................	60.3	34.5	[1]22.6
Total estimated prompt industrial scrap............................	NAp	NAp	213.2

NAp Not applicable.

[1]Calculated by difference between total of 33,900 tons of finished products resulting from 56,500 tons of semifinished products consumed outside of steel mills; see table 1.

Source: Arthur D. Little, Inc., estimates.

After adding prompt industrial scrap produced from consumption of bars, sheet and strip, etc., total prompt industrial scrap generated from consumption of finished shapes is 190,600 tons. To this we add the 22,600 tons of prompt industrial scrap estimated earlier as resulting from conversion of semifinished steel mill products to finished forms. As a result, total prompt scrap generation is calculated to be 213,200 tons (table 2).

Obsolete Scrap

Production of Manufactured Goods

As discussed on pages 12-14, estimates of prompt industrial scrap in 1977 were calculated on the basis of yield losses occurring during the manufacture of consumer goods from stainless steel mill products. By calculating the difference between prompt industrial scrap generation and apparent domestic consumption of stainless steel mill products, the amount of stainless steel actually entering the manufactured product can be estimated:

$$\left\{\begin{matrix}\text{tons of stainless steel}\\ \text{in manufactured products}\end{matrix}\right\} = \left\{\begin{matrix}\text{tons of stainless}\\ \text{steel mill products}\end{matrix}\right\} - \left\{\begin{matrix}\text{tons of prompt indus-}\\ \text{trial scrap generated}\end{matrix}\right\} \quad (13)$$

At the end of a manufactured product's life, obsolete scrap is generated. To calculate the tons of obsolete scrap generated, one needs estimates of the tons of stainless steel originally used in the manufacture of goods being discarded in 1977.

Recognizing that the methodology used in this study calls for distributing lives of manufactured goods into short-term (10-year lives) and long-term (20-year lives) categories, estimates were first made of the tons of stainless steel entering goods manufactured in 1967 and 1957, starting with table 3, which shows published statistics on apparent domestic consumption of steel mill products by market classification for 1967. Two adjustments were made to table 3. In estimating prompt industrial scrap generation in 1977 at the beginning of this section, yields of 60 percent were assumed from semifinished to finished steel mill products. Similarly, in making the first adjustment to table 3, the semifinished products of table 3 were allocated to finished stainless steel mill product categories in table 4 by using a 60-percent yield. Steel mill goods resulting from the semifinished product were distributed in proportion to apparent consumption of finished steel mill products. A second adjustment was then made because of a lack of data for making lifetime estimates for goods in five market classifications: (1) Steel for converting and processing, (2) steel service centers and distributors, (3) exports (reporting companies only), (4) nonclassified shipments, and (5) net imports. As a result, tonnage consumed in these sectors was allocated to the other market sectors in proportion to their apparent domestic consumption as shown in table 3. Results of these two adjustments are shown in table 4 as the adjusted distribution of stainless steel mill product consumption by market classification. Apparent domestic consumption from table 3 and adjusted distribution from table 4 are summarized in the first two numerical columns of table 5.

TABLE 3. - Apparent domestic consumption of stainless steel mill products in 1967 (tons)

Market classifications	Semi-finished products	Wire products	Plates	Bars	Pipes and tubes	Sheet and strip	Total
Steel for converting and processing......	21,524	7,315	257	5,411	715	25,535	60,757
Forgings (not elsewhere classified)......	11,046	0	0	4,010	0	0	15,056
Industrial fasteners....................	38	5,310	0	6,320	0	963	12,631
Steel service centers and distributors...	8,444	17,559	33,265	73,075	17,604	188,906	338,853
Construction, including maintenance......	444	56	628	463	1,289	2,105	4,985
Contractors' products....................	20	325	242	1,552	554	16,666	19,359
Automotive...............................	193	704	702	3,922	291	107,325	113,137
Rail transportation......................	0	0	171	89	48	1,734	2,042
Shipbuilding and marine equipment........	0	70	427	1,257	196	336	2,286
Aircraft.................................	2,220	233	69	8,742	669	3,204	15,137
Oil and gas drilling.....................	413	0	4	211	0	500	1,128
Mining, quarrying and lumbering..........	0	0	55	190	0	291	536
Agricultural.............................	0	8	0	52	3	728	791
Machinery, industrial equipment and tools	1,214	5,616	3,350	20,003	6,684	16,359	53,226
Electrical machinery and equipment.......	52	1,175	485	9,934	1,397	6,218	19,261
Appliances, utensils, and cutlery........	0	309	115	3,288	84	48,043	51,839
Other domestic and commercial equipment..	0	269	310	1,643	629	14,096	16,947
Containers, packaging and shipping materials.............................	0	0	62	504	40	1,491	2,097
Ordnance and other military..............	28	84	300	834	225	4,193	5,664
Export (reporting companies only)........	33	214	475	1,622	788	62,804	65,936
Nonclassified shipments..................	530	617	19,617	7,215	5,265	2,168	35,412
Total domestic shipments.............	46,199	39,864	60,534	150,337	36,481	503,665	837,080
Net imports..........................	-27,405	24,706	1,691	6,763	2,188	26,400	34,342
Apparent domestic consumption.......	18,794	64,570	62,225	157,099	38,669	530,065	871,422

Sources: Domestic Shipments from AISI, (1).
Net Imports from Department of Commerce (14).

TABLE 4. - Adjusted distribution of stainless steel mill products by market classification in 1967 (tons)

Market classifications	Semi-finished products	Wire prod-ucts	Plates	Bars	Pipes and tubes	Sheet and strip	Total
Steel for converting and processing......	0	0	0	0	0	0	0
Forgings (not elsewhere classified)......	0	0	0	10,129	0	0	10,129
Industrial fasteners.....................	0	24,536	0	15,965	0	2,306	42,807
Steel service centers and distributors...	0	0	0	0	0	0	0
Construction, including maintenance......	0	259	5,722	1,170	4,171	5,041	16,362
Contractors' products....................	0	1,502	2,205	3,920	1,793	39,914	49,334
Automotive...............................	0	3,253	6,396	9,907	942	257,039	277,537
Rail transportation......................	0	0	1,558	225	155	4,153	6,091
Shipbuilding and marine equipment........	0	323	3,890	3,175	634	805	8,828
Aircraft.................................	0	1,077	629	22,083	2,165	7,673	33,626
Oil and gas drilling.....................	0	0	36	533	0	1,197	1,767
Mining, quarrying and lumbering..........	0	0	501	480	0	697	1,678
Agricultural.............................	0	37	0	131	10	1,744	1,922
Machinery, industrial equipment and tools	0	25,950	30,522	50,529	21,627	39,179	167,806
Electrical machinery and equipment......	0	5,429	4,419	25,094	4,520	14,892	54,354
Appliances, utensils, and cutlery.......	0	1,428	1,048	8,306	272	115,061	126,114
Other domestic and commercial equipment.	0	1,243	2,824	4,150	2,035	33,759	44,012
Containers, packaging and shipping materials..............................	0	0	565	1,273	129	3,571	5,538
Ordnance and other military.............	0	388	2,733	2,107	728	10,042	15,998
Export (reporting companies only).......	0	0	0	0	0	0	0
Nonclassified shipments.................	0	0	0	0	0	0	0
Total.............................	0	65,424	63,048	159,176	39,180	537,075	863,903

TABLE 5. - Adjusted distribution of stainless steel in manufactured goods by market classification in 1967

Market classifications	Apparent domestic consumption, net tons	Adjusted domestic consumption, net tons	Prompt industrial scrap, net tons	Manufactured goods, net tons	Manufactured goods distribution, percent
Steel for converting and processing	60,757	0	0	0	0.00
Forgings (not elsewhere classified)	15,056	10,129	4,051	6,078	0.85
Industrial fasteners	12,631	42,807	9,128	33,679	4.72
Steel service centers and distributors	338,853	0	0	0	0.00
Construction, including maintenance	4,985	16,362	2,399	13,963	1.96
Contractors' products	19,359	49,334	7,218	42,116	5.91
Automotive	113,137	277,537	37,472	240,065	33.66
Rail transportation	2,042	6,091	858	5,233	0.73
Shipbuilding and marine equipment	2,286	8,828	2,050	6,778	0.95
Aircraft	15,137	33,626	10,211	23,415	3.28
Oil and gas drilling	1,128	1,767	368	1,399	0.20
Mining, quarrying and lumbering	536	1,678	354	1,324	0.19
Agricultural	791	1,922	276	1,646	0.23
Machinery, industrial equipment and tools	53,226	167,806	34,445	133,361	18.70
Electrical machinery and equipment	19,261	54,354	13,557	40,797	5.72
Appliances, Utensils, and cutlery	51,839	126,114	18,032	108,082	15.15
Other domestic and commercial equipment	16,947	44,012	6,631	37,381	5.24
Containers, packaging and shipping materials	2,097	5,538	1,053	4,485	0.63
Ordnance and other military	5,664	15,998	2,619	13,379	1.88
Export (reporting companies only)	65,936	0	0	0	0.00
Nonclassified shipments	35,412	0	0	0	0.00
Net imports	34,342	0	0	0	0.00
Total	871,422	863,903	[1]150,722	713,181	100.00

[1]Excludes prompt industrial scrap from conversion of semifinished products to finished steel mill products.

Sources: Table 3 and Arthur D. Little, Inc., calculations.

To determine the tons of stainless steel used in manufactured goods, we calculate scrap generated in the manufacturing process (such as prompt industrial scrap generated in 1967) as was done for the year 1977 at the beginning of this section. For example, in the industrial fastener sector, 24,536 tons of wire products, 15,965 tons of bars, and 2,306 tons of sheet and strip were consumed with estimated prompt industrial scrap generation rates of 10, 40, and 12.5 percent, respectively. Table 5 shows that in 1967 this resulted in prompt industrial scrap generation in the "industrial fasteners" sector of 9,128 tons (0.10 x 24,536 + 0.40 x 15,965 + 0.125 x 2,306). Thus, of the 42,807 tons of steel mill products consumed in the fasteners sector, 9,128 became scrap and the difference of 33,679 became a part of manufactured goods in 1967 as summarized in table 5. Similar calculations were performed to determine the stainless steel consumed by goods manufactured in the other market classifications. Results, as shown in table 5, indicate that manufactured goods in 1967 consumed 713,181 tons of the 871,422 tons of apparent domestic consumption, with the difference of 158,241 tons reporting to scrap. The last column of table 5 shows the percent distribution of stainless steel by consuming sector.

Finally, an adjustment was made to eliminate biases that could be introduced if the year 1967 were an unusually high or low year for apparent domestic consumption. From the regression equation (equation 12) developed earlier in this study, a rounded value for apparent domestic consumption was calculated to be 874,000 tons, compared with the published data of 871,400 tons as shown in table 5. Tonnage shipments by markets shown in table 6 were arrived at by multiplying 874,000 by the percent distribution by market classification shown in table 5.

Similarly, starting with published data for the year 1957 as shown in appendix A, this same procedure was followed to estimate consumption of stainless steel in manufactured goods with results summarized in table 6. However, there is one exception; namely, data on exports and imports on stainless steel mill products were not readily available for 1957. The regression equation on imports extrapolated back to 1957 indicates minus 13,000 tons of net imports (in other words exports) in 1957, which is about 3 percent of domestic shipments. Because it was suspected that exports were relatively small and in the absence of better available data, a value of zero was assigned to net stainless steel imports in 1957. This is equivalent to assuming apparent domestic consumption is equal to domestic shipments in 1957.

Product Lifetimes

With few exceptions, published data on product lives by market classification were not available. Product lives were estimated by determining through discussions with manufacturers and recyclers what fraction of the goods manufactured in a market sector in a given year could be expected to have a 10-year (±5 years) life and what fraction could be expected to have a 20-year (±5 years) life. For example, in the appliances, utensils, and cutlery classification, 90 percent of the products were estimated to have a 10-year average life and 10 percent a 20-year average life, and all products in the automotive sector were estimated to have a 10-year life (10). The results of this study on lifetime estimates in the other market classifications are shown in table 7.

TABLE 6. - Calculated use of stainless steel in manufactured goods by market classification

Market classifications	1957		1967	
	Manufactured goods distribution, percent	Calculated manufactured goods, tons	Manufactured goods distribution, percent	Calculated manufactured goods, tons
Steel for converting and processing.........	0.0	-	0.0	-
Forgings (not elsewhere classified).........	1.46	7,185	.85	6,080
Industrial fasteners........................	2.92	14,371	4.72	33,762
Steel service centers and distributors......	.0	-	.0	-
Construction, including maintenance.........	4.23	20,818	1.96	14,020
Contractors' products.......................	4.95	24,361	5.91	42,274
Automotive..................................	35.69	175,645	33.66	240,766
Rail transportation.........................	.80	3,937	.73	5,222
Shipbuilding and marine equipment...........	.91	4,479	.95	6,795
Aircraft....................................	6.99	34,401	3.28	23,462
Oil and gas drilling........................	.22	1,083	.20	1,431
Mining, quarrying, and lumbering............	.20	984	.19	1,359
Agricultural................................	.26	1,280	.23	1,645
Machinery, industrial equipment, and tools..	19.10	93,998	18.70	133,759
Electrical machinery and equipment..........	3.97	19,538	5.72	40,915
Appliances, utensils, and cutlery...........	11.71	57,630	15.15	108,367
Other domestic and commercial equipment.....	4.85	23,869	5.24	37,481
Containers, packaging and shipping materials	.59	2,904	.63	4,506
Ordnance and other military.................	1.15	5,660	1.88	13,447
Export (reporting companies only)...........	.0	-	.0	-
Nonclassified shipments.....................	.0	-	.0	-
Total.....................................	100.0	492,143	100.0	715,291

TABLE 7. - Estimated obsolete scrap generation in 1977

Market classifications	Long-lived goods		Short-lived goods		Total obsolete scrap generated in 1977, tons
	Percent in market classification with 20-year average life	Stainless steel content of goods manufactured in 1957 and discarded in 1977, tons	Percent in market classification with 10-year average life	Stainless steel content of goods manufactured in 1967 and discarded in 1977, tons	
Forgings	90	6,467	10	608	7,075
Industrial fasteners	65	9,341	35	11,817	21,158
Construction, including maintenance	55	11,450	45	6,309	17,759
Contractors' products	90	21,925	10	4,227	26,152
Automotive	0	0	100	240,766	240,766
Rail transportation	100	3,937	0	0	3,937
Shipbuilding and marine equipment	100	4,479	0	0	4,479
Aircraft and aerospace	5	1,720	95	22,289	24,009
Oil and gas industry	30	325	70	1,002	1,327
Mining, quarrying, and lumbering	50	492	50	1,223	1,715
Agricultural	10	128	90	1,481	1,609
Machinery, industrial equipment, and tools	50	46,999	50	66,880	113,879
Electrical equipment	60	11,723	40	16,366	28,089
Appliances, utensils, and cutlery	10	5,763	90	97,530	103,293
Other domestic and commercial equipment	15	3,580	85	31,859	35,439
Containers, packaging, and shipping materials	5	145	95	4,281	4,426
Ordnance and other military	5	283	95	12,775	13,058
Total	NAp	128,757	NAp	519,413	648,170

NAp Not applicable.

Obsolete Scrap Calculation

By multiplying 1967 consumption of 108,367 tons in the "appliances, utensils, and cutlery" classification (table 6) by 0.90 and the 1957 consumption of 57,630 tons by 0.10, one arrives at 97,530 and 5,763 tons of obsolete scrap respectively for 10-year life and 20-year life categories. This gives a total of 103,293 tons of obsolete stainless steel scrap generated in this category as shown in table 7. Results of applying the same procedure to the other market sectors are also summarized in table 7, showing total estimated obsolete scrap generation to be 648,170 net tons, which is rounded off to 648,000 net tons in further calculations.

Total Stainless Steel Scrap Generated

Table 8 shows the estimated total of prompt industrial and obsolete scrap generated in 1977 to be 861,000 tons. The fraction of this scrap that is actually recycled is estimated after determining stainless steel scrap exports and imports.

TABLE 8. - Estimated total stainless steel scrap generation in 1977 (thousand tons)

Prompt industrial scrap (table 2)	213
Obsolete scrap (table 7)	648
Total	861

Scrap Collection (Published Data)

Scrap Receipts

In its monthly Mineral Industry Surveys (13), the Bureau of Mines shows statistics gathered on stainless steel scrap. The statistics of interest are classified under the category of receipts of scrap by melters from brokers, dealers, and outside sources which amounted to 424,000 tons in 1977 as described in appendix E.

Foreign Trade

Part of the stainless (and heat-resisting alloy) scrap collected domestically is exported, with exports in 1977 amounting to about 75,000 net tons, as shown in table 9. It appears that 1977 was a normal year in terms of stainless steel scrap exports. No indication was found that the chromium shipped out of the country contained in stainless steel was any less desirable than that which was recycled domestically.

TABLE 9. - U.S. stainless steel scrap exports (thousand tons)[1]

1974	35.0
1975	76.9
1976	112.2
1977	74.7

[1]Data reported in gross tons by Teplitz (11), multiplied by 1.12 to obtain net tons.

Imports of stainless steel scrap are included in U.S. Department of Commerce statistics shown in table 10, as part of the 65,956 tons of ferrous scrap on which an import duty was levied. Scrap dealers and contacts at the U.S. Department of Commerce have commented that stainless and heat-resisting alloys imports are a "very small" portion of that scrap, but data have not been found to quantify such opinions. Thus, three approaches were followed:

1. The phrase "very small" was interpreted to mean that 10 percent (or less) of 66,000 net tons on which imports are based is stainless steel scrap, to arrive at a value of 6,600 net tons of stainless steel scrap.

2. Table 10 shows that iron scrap subject to duty accounts for about 11 percent of ferrous scrap imports, which is approximately the same as alloy and stainless steel production as a percent of total U.S. steel production (including alloy, stainless, and carbon steel grades). AISI statistics indicate that stainless and alloy steel shipments together have been about 10 percent (±2 percent) of total steel shipments. Using those ratios for domestic shipments of steel mill products and assuming they apply to scrap, the following procedure was followed:

Historical records (1) indicate that stainless steel production in the United States over the past 10 years has been about 7 to 14 percent alloy steel production. If it is assumed that ferrous scrap imports on which duties were levied (66,000 tons) exhibit the same ratio of alloy to stainless, one arrives at stainless steel scrap imports of 4,600 to 9,240 net tons (0.07 x 66,000 to 0.14 x 66,000).

3. It is noted that U.S. stainless steel production over the past 29 years has accounted for 0.9 to 1.5 percent of total steel production. If ferrous scrap imports are in the same ratio, calculate 0.9 to 1.5 percent of the 616,000 tons of total ferrous scrap imports to be stainless steel, or 5,500 to 9,200 tons. Combining the three approaches indicates that a likely value for stainless steel scrap imports would fall between 5,000 and 9,000 tons. Seven thousand tons is used in further calculations, which is about 10 percent of the weight of the ferrous imports on which duties are levied. Clearly better import data are needed to confirm these rather subjective estimates.

TABLE 10. - Ferrous scrap imports in 1977 (tons) (14)

Tin plate	12,500
Iron scrap not subject to import duty	537,067
Iron scrap subject to import duty[1]	65,956
Total 1977 imports	615,523

[1]Alloys containing more than any of the following were subject to import duty: 0.2 percent Cr, 0.1 percent Mo, 0.3 percent W, and 0.1 percent V.

Total Prompt Industrial and Obsolete Scrap Collected

Upon addition of net exports to receipts by melters, total prompt industrial and obsolete scrap collected is about 492,000 net tons, as shown in table 11.

TABLE 11. - Domestic scrap collection (thousand tons)

Prompt industrial and obsolete scrap received by melters (domestic receipts)	[1]424
Exports	[2]75
Imports	[3]7
Net exports	68
Total	492

[1]Bureau of Mines (13, May 1978).
[2]American Metal Market (2).
[3]Arthur D. Little, Inc., estimate based on Department of Commerce data.

UNRECOVERED CHROMIUM VALUES

Calculation of Unrecovered Fraction

The quantity (U) of stainless steel values lost or otherwise not recycled can be estimated as the difference between (S) scrap collected (492,000 tons) and (G) scrap generated (861,000 tons). Few direct data are available on this unrecovered scrap (U) amounting to 369,000 tons. The following sections summarize some findings from discussions with recyclers and manufacturers on chromium values that appear to be unrecycled.

Prompt Industrial Scrap

Little prompt industrial scrap is unrecycled since it is not economic for metal fabricators to accumulate rather than sell the scrap they generate. Generally they arrange with a scrap dealer to sell the high-value materials (such as well-segregated solids) provided the scrap dealer takes other scrap as well. This was found to be a common practice for both open spot bids and long-term contract agreements.

Industrial recovery of chromium from the 400-series stainless and heat-resisting alloys has been the subject of some controversy. The chromium in stainless steel is of much less value than the nickel. Before the AOD process was developed, industry contacts indicate that about 15 percent of the total chromium content of the steelmaking furnace charge was lost in slag and dust.

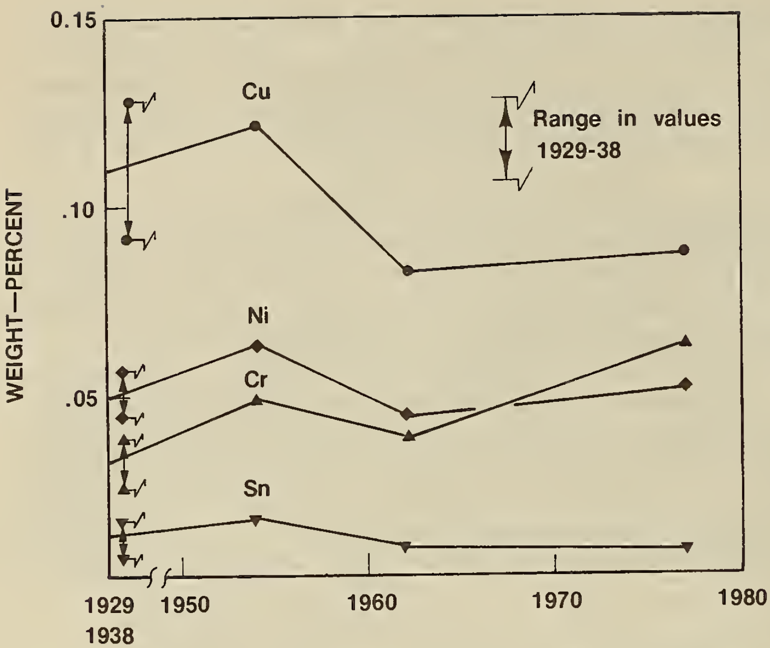
Today, however, chromium recovery is in the 92- to 96-percent range in the duplex electric arc furnace-AOD process, regardless of the ratio of scrap to virgin elements. Well-segregated 400-series stainless steel scrap sells for nearly twice the price of carbon steel scrap and is thus a relatively high valued material that is unlikely to be downgraded. However, two factors hinder the recycling of prompt 400-series stainless steel scrap: transportation costs and contamination. Transportation costs for scrap can be substantial, since the few melters are located mainly in the Midwest or on the East Coast. This geographic imbalance between scrap supply centers and scrap consumption centers slows down trade in 400-series scrap in times of low prices. This does not mean that the scrap will not be recycled, but it may be allowed to accumulate in a scrap yard until prices rise to a level where it becomes economical to sell.

Contamination is a major concern of the recycler. Prompt industrial scrap is usually well segregated into the 400 and 300 series with the latter often segregated into molybdenum-containing and non-molybdenum-containing types. In addition, nickel-chromium steels are almost always segregated and recycled with only small losses since nickel has been a relatively high valued metal. Nickel is recovered upon remelting, losses to slags are small, and furnace dust recycling technologies now coming into increasing use also recover the nickel that previously was not recycled from pollution control equipment dusts and sludges. In addition, proper segregation of nickel-containing stainless steel (mainly the 300 series) permits the recovery of other valuable elements, such as molybdenum in the popular 316 grades.

The only occasional exception is "mixed turnings and borings," which sometimes contain not only various stainless grades but also alloy and carbon steel and perhaps even some free cutting brass.

Here there is a problem of identification as well as contamination. A rail car or truck of such material is a heterogeneous mix that is difficult to sample in a statistically acceptable fashion. One approach that has been adopted is to crush and blend the scrap; the resulting product can be sampled and meaningfully certified and shipped as such or blended to customer specifications.

Based on discussions with scrap dealers and melters, turnings represent less than 25 percent of the total amount of prompt industrial scrap, and at least three-quarters of the turnings are clean enough to be recycled to the stainless steel melting furnace. This leaves less than 14,000 tons of potentially poor quality turnings; some may be exported, but most such turnings appear to be recycled domestically as part of the iron and carbon steel scrap amounting to approximately 45 million tons a year. With the exception of these turnings, nearly all prompt industrial stainless steel scrap is recycled within a relatively short time (less than a few years) after generation.



Source: American Iron and Steel Institute Survey Data from D. Blickwede, Bethlehem Steel, Bethlehem, Pa.

FIGURE 4. - Residual elements in carbon steel manufactured in the United States.

Downgrading

Figure 4 shows that the chromium content of carbon steel produced in the United States for the past several decades has been about 0.05 ± 0.01 percent. Thus, one would expect that carbon steel scrap would have a similar chromium content when goods are discarded at the end of their lives. However, table 12 shows the chromium content of purchased carbon steel scrap to contain an estimated 0.12 percent chromium. Thus, the estimated chromium picked up by the 32,149,000 tons of purchased carbon steel scrap being recycled is about 22,500 tons of contained chromium [32,149,000 (0.12 - 0.05)/100]. Assuming the chromium comes from stainless steel scrap containing 16.7 percent chromium, it is calculated that 135,000 tons of stainless steel scrap was unintentionally mixed with carbon steel scrap. Some of this contamination may be due to the prompt industrial stainless steel turnings (up to 14,000 tons) discussed earlier, but the major source of this contamination appears to be obsolete scrap.

In addition, figure 4 shows that the residual chromium in steel manufactured in the United States has risen from about 0.04 to 0.05 percent in the 1950's and early 1960's to about 0.06 percent in 1977. This amounts to an increase of about 0.001 percent per year. If the increase is attributed to chromium contamination from stainless steel scrap, which seems likely, the amount of stainless steel downgraded can be estimated by assuming an average total steel production of about 120 million tons per year, which when multiplied by 0.001/100 amounts to 1,200 tons of contained chromium, or about 7,000 tons of stainless steel assuming it contains the average 16.7 percent chromium. Upon adding these 7,000 tons to the 135,000 tons found above, we calculate that about 142,000 tons of stainless steel may be downgraded to carbon steel scrap; of this, up to 14,000 tons may arise from prompt industrial stainless steel turnings, and the difference is estimated to be obsolete scrap.

TABLE 12. - Chromium in purchased carbon steel scrap in 1977

Scrap grade	Receipt of scrap by melters from brokers, dealers, and other outside sources, thousand tons	Average chromium content, percent	Total chromium content, tons
Low-phosphorus plates and punchings	1,810	0.06	1,086
Cut structural and plate...........	1,891	.09	1,702
No. 1 heavy melting................	5,953	.10	5,953
No. 2 heavy melting................	2,178	.18	3,920
No. 1 and electric furnace bundles.	6,181	.07	4,327
No. 2 and other bundles............	2,315	.19	4,167
Electric furnace, 1 foot and under.	147	.09	132
Railroad rails.....................	206	.05	103
Turnings and borings...............	1,933	.40	7,732
Slag scrap (Fe content 70 percent).	1,505	.03	451
Shredded or fragmentized...........	2,694	.20	5,398
No. 1 busheling....................	1,910	.03	573
All other carbon steel scrap.......	3,426	.12	4,111
Total carbon steel scrap......	32,149	NAp	39,655

NAp Not applicable.

Obsolete Scrap Collection

As already indicated, not all obsolete scrap generated is collected. Small household items such as cutlery, flatware, and toasters usually join the mainstream of municipal solid waste and are generally not recovered. Based on discussions with recyclers, we estimate that possibly half of the stainless steel used in underground mining and drilling for oil and gas is never recovered; stainless steel screws, decorative trim on buildings, and stainless valves and fittings are not normally recovered.

Estimates based on discussions with recyclers indicate that about 80 percent of all junked automobiles are collected; the remaining 20 percent are abandoned in backyards or remote sites. However, between 10 and 20 percent of the collected junked automobiles are baled with only the wheel covers and hubcaps recovered. Shredders do a slightly better job at recovering the stainless steel. However, since the 400-series fraction is magnetic, it is lost with the fragmented steel portion, which is the reason shredded steel (automotive) scrap has about 0.2 percent chromium versus the carbon-steel scrap average of 0.12 percent chromium. The nonferrous (nonmagnetic) stream is sent to a metal recovery plant from about 75 percent of domestic shredding operations; the other 25 percent apparently send the nonmagnetic stream to landfill operations. A multistage, sink-float process produces fractions containing mainly light organics, heavy rubber and plastics, aluminum, and heavier nonmagnetic metals like stainless steel, zinc, and copper. A rotary furnace melts and separates the zinc, and the stainless steel is separated from the copper with varying degrees of efficiency by hand picking. The copper goes to refineries; the stainless steel, which contains about 2 percent copper and other contaminants and is recovered with about an 80 percent

efficiency, is sold to a stainless steel melter. Overall, this gives a recovery factor for stainless steel in automobiles of about 30 to 40 percent. Based upon these rather subjective opinions, table 13 was developed in an attempt to quantify and reconcile the apparent large quantity of obsolete scrap from which chromium is not recovered. The largest single sector showing unrecovered stainless steel scrap is the automotive sector, followed by the appliances, utensils and cutlery sector.

TABLE 13. - Estimated obsolete stainless steel scrap recovered in 1977

Market classifications	Estimated total obsolete scrap generation, thousand tons	Obsolete scrap generated that is recycled for recovery of Cr		Obsolete scrap unrecycled for Cr recovery,[1] thousand tons
		Percent	Thousand tons	
Forgings	7	60-80	4-6	1-3
Industrial fasteners	21	20-50	4-10	11-17
Construction, including maintenance	18	20-60	4-11	7-14
Contractors' products	26	20-70	5-18	8-21
Automotive	241	30-40	72-96	145-169
Rail transportation	4	60-80	2-3	1-2
Shipbuilding and marine equipment	5	60-80	3-4	1-2
Aircraft and aerospace	24	50-80	12-19	5-12
Oil and gas industry	1	40-60	0-1	0-1
Mining, quarrying, and lumbering	2	40-60	1-1	1-1
Agricultural	2	40-60	1-1	1-1
Machinery, industrial equipment, and tools	114	50-70	57-80	34-57
Electrical equipment	28	40-60	11-17	11-17
Appliances, utensils, and cutlery	103	10-30	10-31	72-93
Other domestic and commercial equipment	35	10-30	4-11	24-31
Container, packing and shipping materials	4	60-80	2-3	1-2
Ordnance and other military	13	10-30	1-4	9-12
Total	648	NAp	193-316	332-455

NAp Not applicable.
[1]Downgraded or unrecovered.

Source: Arthur D. Little, Inc., estimates.

Reconciliation

Reported receipts and exports of prompt industrial and obsolete stainless steel scrap are about 492,000 tons as indicated in table 14. Such a value falls within the calculated range of 392,000 to 515,000 tons of stainless steel recovered for recycling of chromium values. Based on the 492,000 tons as a "best estimate" for stainless steel scrap recovered for chromium values, one concludes from table 14 that stainless steel which is unrecovered or downgraded amounts to 369,000 tons, of which an estimated 142,000 tons was downgraded and 227,000 tons went unrecovered. Based on an average chromium content of 16.7 percent in the 369,000 tons, 62,000 tons of chromium went unrecovered in 1977.

TABLE 14. - Reconciliation of reported values with calculated values of stainless steel scrap recovered for chromium values in 1977 (thousand tons)

Source of data	Unrecovered	Downgraded	Recovered for recycling of Cr	Total generated
As determined by this study:				
Prompt industrial	Nil	[1]14	[2]199	213
Obsolete scrap	[3]204-327	128	193-316	648
Total	204-327	142	392-515	861
Reported receipts by melters and net exports of prompt industrial and obsolete scrap	NA	NA	[4]492	NA
"Best estimate" used in further discussions	227	142	492	861

NA Not available.
[1]Estimated to be no greater than 14.
[2]Calculated by the difference between 14 and 213.
[3]Calculated by the difference between columns (2 + 3) and 4.
[4]Errors in estimating imports may add up to 58,000 tons of the 492,000 tons shown (see text).

Source: Arthur D. Little, Inc., estimates.

Estimates of Potential Error

Scrap Imports

As discussed in the section on scrap collection and foreign trade, a likely value for stainless steel scrap imports was 7,000 tons in 1977, but the value could be as high as 66,000 tons. If scrap imports are increased by 59,000 tons, it would increase uncollected domestic scrap by a like amount.

Yields in Manufacture

The magnitude of other potential errors can be best evaluated from an examination of equation 9 for uncollected scrap:

$$U = (D - Y_{av}D)_{77} + (Y_{av}D)_t - S_{77}. \qquad (9b)$$

Substituting apparent domestic consumption of steel mill products (D) for the years 1977 and the year (t) (t = T in equation 4b) into equation 9 and assuming an average yield in manufacturing invariant with time:

$$U = A + 77B - Y_{av}(A + 77B) + Y_{av}(A + 64B) - S_{77}$$

$$= A + 77B - Y_{av}B(77 - t) - S_{77}. \qquad (14)$$

The parameters A and B have been determined from a linear regression equation for apparent domestic consumption and are treated as constants. Domestic shipments account for more than 90 percent of apparent domestic consumption. Thus, we believe that little accuracy is lost by lack of net import data on stainless steel mill products before 1964. From appendix B we see that the average calculated yield, Y_{av}, ranges from 0.80 to 0.83 in the years 1957 to 1977. Some industry respondents have expressed the belief that such a value is of the right order of magnitude, while others have expressed alternative views indicating a range in opinion that $Y_{av} \approx 0.8$ may be off by ±0.1. Recognizing that parameter B has a value of 27.24 (thousand tons per year) and t of about 64 (see appendix D), the impact on U is given as a change in U, or ΔU:

$$\Delta U = B(77-t)\ \Delta Y_{av}$$

$$= (27.24)(77-64)(0.1)$$

$$= 35{,}000 \text{ tons of uncollected stainless steel scrap.} \qquad (15)$$

When compared with our "best value" of 369,000 tons of unrecovered (or downgraded) stainless steel scrap, it seems that the potential error in yield values would impact our results by under 10 percent.

Prompt Industrial Scrap Generation

Although most of the yield loss in manufacturing goods from steel mill products can be accounted for by scrap, discussions with manufacturers indicate there are other losses such as grinding swarf which might amount to a few percent (at most) of consumption. If it is assumed that a loss rate of 2 percent can be applied to all steel mill shipments in 1977 (1,120,000 tons), it is calculated that such losses may be 22,000 tons. This would reduce prompt industrial scrap generation and total uncollected scrap by a like amount.

Average Lifetimes

While few industry sources have questioned the lifetime estimates for short-lived goods containing stainless steel (those having lives of 10 years or so), a few contacts have expressed some concern about the long-lived products (goods having lives of about 20 years). Basically these contacts feel that some stainless steel goods in the market classifications shown in table 7 would last more than 20 years. Thus, they suspect the average year for manufacturing such long-lived goods was some time prior to 1957 if the goods were discarded in 1977. Opinions expressed exhibit an upper limit to average life cycles in the long-lived product category of 25 years; in other words, long-lived stainless steel goods were allotted a range of lives from 15 to 35 years. The impact of such an assumption is estimated as follows:

If they appeared as obsolete scrap in 1977, goods with 25-year average lives were manufactured in 1952. From equation 12, estimated apparent domestic consumption of stainless steel mill products was 465,000 tons in 1952. Based on an average yield from steel mill products to manufactured goods of 0.8 (appendix B), stainless steel entering consumer goods in 1952 amounted to 372,000 tons (465 x 0.8). As a result the total tons of stainless steel in the column labeled "1957" of table 6 would be adjusted downward from 492,143 to about 372,000 tons, or a reduction of 24 percent. A similar downward adjustment of 24 percent would be made in table 7 for "long-lived goods" which would reduce obsolete scrap generation as well as total scrap generation (G) by 31,000 tons (rounded from 128,757 x 0.24). As seen in equation 9, uncollected stainless steel scrap in 1977 would be reduced by a similar amount.

Thus, a 5-year increase in the average lifetime of the long-lived goods would reduce uncollected scrap (U) in 1977 by 31,000 net tons.

Imports and Exports of Manufactured Goods

Obviously imported goods containing stainless steel that are manufactured abroad, such as automobiles, contribute to obsolete scrap generation. If goods manufactured domestically are exported, such goods would typically not add to domestic obsolete scrap generation at the end of the products' lives. Imports and exports of manufactured goods containing stainless steel have been neglected in this study. Because data were unavailable on the amount of stainless steel in manufactured goods that are exported or imported it is impossible to quantify any potential errors that may occur by neglecting such exports and imports. However, except in a few instances (for example, automobiles, utensils, machinery) imports or exports containing large amounts of stainless steel have not been identified. Based on industry contacts, it is estimated that manufactured goods exported or imported would be well under 20 percent and more likely under 10 percent. The impact of a 10-percent increase in imports of manufactured goods containing stainless steel would increase obsolete scrap generation by a like amount. Since obsolete scrap generation is estimated to be 648,000 tons (table 8), a 10-percent increase in imports would add about 65,000 tons to uncollected domestic scrap.

Corrosion

Losses resulting from corrosion, erosion, and general wear are extremely difficult to estimate, and no data have been found with regard to stainless steel on which to base a calculation. In an earlier study, Nathan Associates (8-9) estimated that uncollected carbon steel scrap in inventory corrodes by about 0.36 percent per year. Stainless steel is expected to corrode less, but is is not known how much less. In addition, we have seen no estimates of erosion and wear of stainless steel parts in service. If a 1-percent annual loss rate resulting from corrosion, erosion, general wear, etc., is accepted, this would amount to about 10,000 tons annually (that is, 1 percent of approximately 1 million tons of stainless steel scrap used in manufactured goods). However, it should be recognized that such a calculation is based on almost no data and could be subject to a potentially large error.

Superalloy Downgrading

As discussed, some chromium losses occur by downgrading of stainless steel scrap to carbon steel. In a prior study (5) an opinion gathered by discussions with superalloy dealers indicated that downgrading of superalloys to stainless steel scrap also occurs, but only rarely. Based on these discussions, it is estimated that such downgrading amounted to less than 10,000 tons of superalloys, with average chromium contents in the same range as in stainless steels. This has the effect of increasing uncollected stainless steel scrap by up to 10,000 tons.

Allocation of Steel Mill Products

Although it is believed that the methodology (involving allocation of semifinished steel mill products, shipments to service centers, net imports, etc., to other categories) leads to only small potential errors in determining scrap generation, this procedure may involve significantly larger potential errors in determining the relative importance of one market classification as opposed to another in terms of uncollected scrap. Examination of tables 3 and 4 shows that the largest unknown involves shipments by steel service centers, which account for about 35 to 40 percent of apparent domestic consumption of stainless steel. Clearly, better data are needed on shipments by steel service centers before doubts on the relative amounts of stainless steel shipments to different sectors of the economy can be eliminated.

Future Work

The potential errors in the factors leading to estimates in (U) (unrecycled or unrecovered scrap) are compared in table 15. It is seen that potential errors can be up to 10 to 20 percent of the estimated 369,000 tons of uncollected scrap and that the most significant factors are--

1. Neglecting imports and exports of manufactured goods containing stainless steel.

2. Estimating stainless steel scrap imports.

3. Estimating scrap losses in manufacturing.

4. Lifetime estimates for long-lived goods containing stainless steel.

Obviously if the price of chromium rises substantially, a larger fraction of chromium scrap generated would be expected to be collected. The effect of chromium prices on chromium scrap recycling has not been analyzed in this study.

Outside of the category of erosion, corrosion, etc., where little data is available, the other factors examined appear to add only a small contribution to unrecovered chromium.

TABLE 15. - Potential error summary[1] (thousand tons)

Potential error summary (ΔU equation 15)	Change in uncollected scrap (U)	
	Negative changes	Positive changes
10-percent increase or decrease of net imports of manufactured goods	-65	+65
Imports of scrap (limits in range)	-7	+59
Potential errors in yield losses to scrap ($1 - Y_{av}$) in manufacturing operations	-35	+35
Increase in life cycle of "long-lived" goods containing stainless steel by 5 years	-30	0
Prompt industrial scrap yield losses to scrap reduced by 2 percent and other losses (for example, grinding swarf increased by 2 percent)	-22	0
1-percent annual loss rate resulting from erosion, corrosion, etc	-10	0
Downgrading of superalloys to stainless steel	0	<+10
Downgrading stainless steel to carbon steel scrap	-7	0

[1]Base case summary for 1977:

Generated (table 8)	861
Collected (table 11)	492
Uncollected or downgraded (U)	369

Projections

Using equation 9b, projections can be made based on historical consumption patterns. Substituting the relationship for apparent domestic consumption of stainless steel (equation 4b) in the future year T' (expressed, for example, as '83, '90, and so on) and in the year t,

$$U = A + BT' - Y_{av}\ B\ (T'-t) - S_{77}. \tag{16}$$

Recognizing that T'-t is the life cycle for goods containing stainless steel, or about 13 years (appendix D), and that $Y_{av} \simeq 0.82$ (appendix B), B = 27.24, and A = -951.3 (see equation 12), equation 16 yields these values:

$$U = -951.3 + 27.24\ T' - 0.82\ (27.24)(13) - S_{T'} \tag{17a}$$

$$= \underbrace{27.24T' - 1,241.68}_{\text{scrap generation}} - \underbrace{S_{T'}}_{\text{scrap collection}} \tag{17b}$$

Based on this equation, stainless steel scrap generation in 1977 was 856,000 tons (27.24 x 77 - 1,241.68), compared with 861,000 tons as shown in table 8. The difference is largely due to using reported data in table 8 as a basis for determining apparent domestic consumption in 1977 rather than a value calculated by linear regression for 1977 using equation 4b. Table 15

shows that in 1977 scrap recovered (492,000 tons) amounts to 57 percent of the 861,000 tons generated [S = 0.57G = 0.57 (27.24T - 1,241.68)]. If this same ratio holds in future years,

$$S_{T'} = 0.57\ (27.24T' - 1{,}241.68). \qquad (18)$$

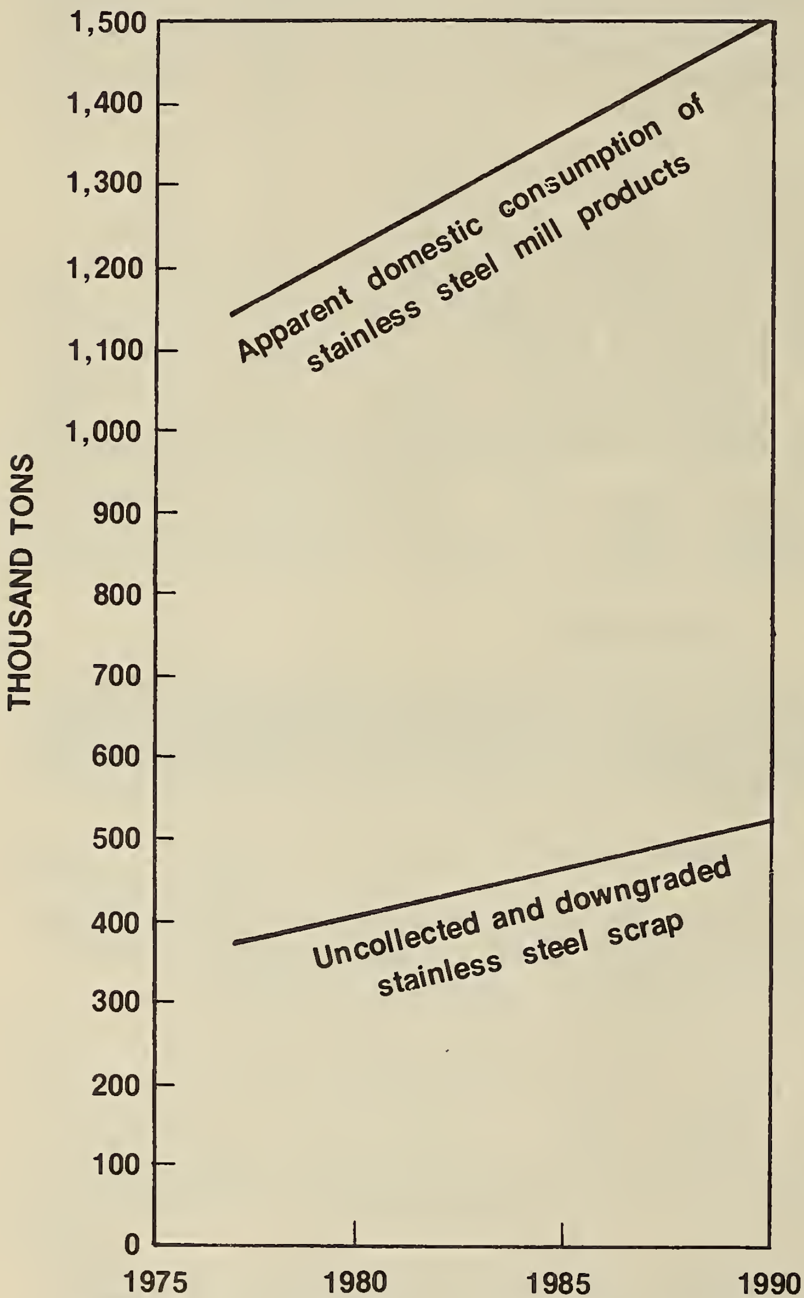


FIGURE 5. - Trendline projections of apparent domestic consumption and uncollected and downgraded stainless steel scrap.

Substituting equation 18 into equation 17b yields the uncollected scrap in the year T':

$$U = 11.71T' - 533.92. \qquad (19)$$

Equations 12 and 19 are plotted in figure 5 showing that the trendline projection to 1990 indicates apparent domestic consumption of 1,500,000 tons and uncollected or downgraded stainless steel scrap of 520,000 tons.

The most significant factor that may impact the amount of stainless steel recycled in the mid-1980's and later is believed to be the degree of recycling of automobile catalytic convertor shells made from type 409 stainless steel. If removed from junk automobiles to recover the catalyst, the shells may well be segregated for recycling. If not removed, this 409 stainless steel would largely report to the magnetic fraction in a shredding operation, which would hinder subsequent recovery for chromium values. Industry contacts indicate that the convertor shell weighs about 35 pounds and that there may be other ways of meeting emission control laws. Nevertheless, if we assume that all U.S.-made automobiles (about 10 million

cars a year) will have a 35-pound stainless steel convertor shell, about 175,000 tons of junk convertor shells can be expected annually in the 1990's (assuming the shell lasts the life of the automobile). Clearly, this represents a significant source of chromium.

SUMMARY

This study focused on estimating uncollected stainless steel scrap. Home scrap is largely recycled and thus was not in the scope of this study.

Figure 6 summarizes flows of stainless steel products and scrap as determined from this study. Uncollected scrap was calculated as the difference between domestic stainless steel scrap collected (as reported by the Bureau of Mines) and the scrap generated. Estimates of prompt industrial scrap generated were obtained from apparent domestic consumption of steel mill products. It was found that nearly all prompt stainless steel industrial scrap generated is collected. Obsolete scrap generation calculations were made by estimating product lifetimes and the quantity of stainless steel used to manufacture the product. It was found that most of the stainless steel scrap that is unrecovered arises from obsolete scrap.

As shown in figure 6, about one-third of the obsolete scrap appears to go unrecovered. It is suspected, but not substantiated, that most of this unrecovered scrap arises from stainless steel used in appliances, utensils, and cutlery.

Of the estimated 421,000 tons of obsolete scrap recovered, it is estimated that 142,000 tons are downgraded or unintentionally mixed with carbon-steel scrap. Most of this loss of chromium values apparently arises from junk automobiles. Addition of this 142,000 tons downgraded to 227,000 tons unrecovered yields 369,000 tons of stainless steel unrecovered and downgraded.

Overall, figure 6 shows that about three-quarters of the obsolete and prompt industrial stainless steel scrap generated is recycled, but not always for chromium recovery. Chromium values lost in 1977, assuming 16.7-percent chromium in stainless steel, are estimated to be 62,000 tons (369 x 0.167). Trendline projections to 1990 indicate that the uncollected and downgraded stainless steel fraction can be expected to rise to 520,000 tons with about 87,000 tons of contained chromium. A major unknown involves estimating the amount of automotive catalytic convertor shells (made largely of the magnetic 409 stainless steel grade) that will be recycled.

Major data gaps identified in this study that can affect the above conclusions by 10 percent or more on the amount of stainless steel scrap uncollected include (1) stainless steel contained in imports and exports of manufactured goods, (2) imports of stainless steel scrap, (3) estimates in yield losses to scrap in the manufacture of stainless steel goods from mill products, and (4) lifetime estimates of long-lived stainless steel goods.

Better data are needed in these sectors to quantify more definitively the amount of uncollected stainless steel scrap. In addition, it would appear worthwhile to examine whether there are any technological problems in recycling catalytic convertor shells from junk automobiles.

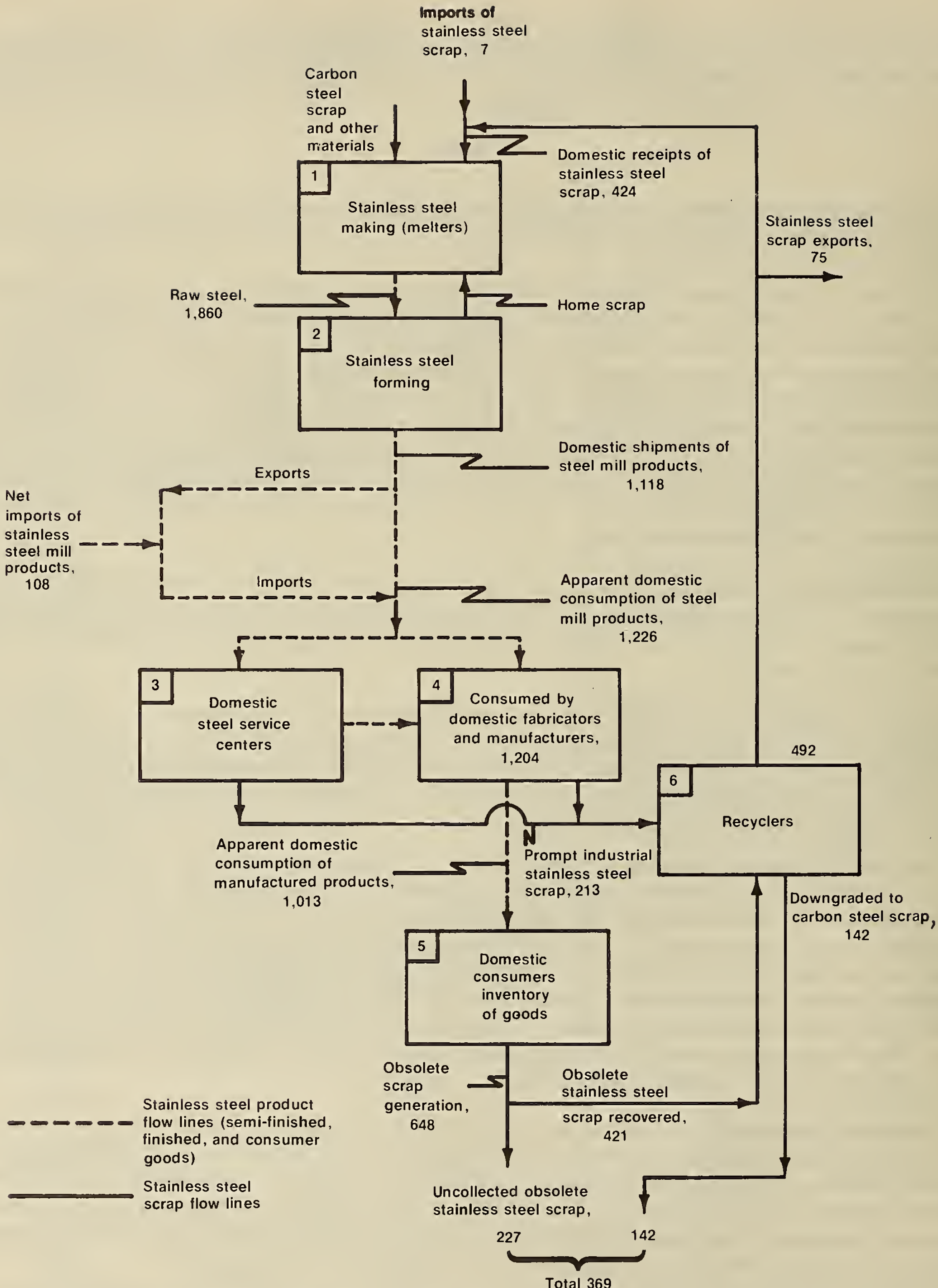


FIGURE 6. - Estimated flow of stainless steel products and stainless steel scrap between producers and consumers in 1977; numbers show estimated flows in thousand net tons of stainless steel.

REFERENCES

1. American Iron and Steel Institute. Annual Statistical Reports (sections on raw steel production and shipments--steel products). Washington, D.C., 1957-77.

2. American Metal Market Co. Steel. Ch. in Metal Statistics (published annually). Fairchild Publications, New York, 1957-77.

3. Curwick, L. R., W. A. Petersen, and H. V. Makar. Availability of Critical Scrap Metals Containing Chromium in the United States. Superalloys and Cast Heat- and Corrosion-Resistant Alloys. BuMines IC 8821, 1980.

4. Institute of Scrap Iron and Steel, Inc. Specifications for Iron and Steel Scrap. Washington, D.C., 1975, pp. 13-16.

5. Kusik, C. L., and C. B. Kenahan. Energy Use Patterns for Metal Recycling. BuMines IC 8781, 1978, pp. 112-124.

6. McGannon, H. E. (ed.). The Making, Shaping and Treating of Steel. United States Steel Corporation, Pittsburgh, Pa., 9th ed., 1971, pp. 1163-1202.

7. Parker, E. R. (Committee Chairman). Contingency Plans for Chromium Utilization. National Materials Advisory Board, National Research Council, National Academy of Sciences, Washington, D.C., 1978, 374 pp.

8. Phoenix Quarterly. Potential Scrap Harvest Grows. V. 10, No. 3, Fall 1978, p. 3.

9. Robert R. Nathan Associates, Inc. Iron and Steel Scrap--Its Accumulation and Availability. Washington, D.C., 1977, pp. 78-80.

10. Shonka, D. B., A. S. Loebl, and P. D. Patterson. Transportation Energy Data Book. Oak Ridge National Laboratory, Report ORNL-5320, 2d ed., 1977, 567 pp.

11. Teplitz, B. (ed). American Metal Market. Nickel Stainless Supplement. Fairchild Publications, New York, Nov. 10, 1978, p. 20. (Export data are credited to Institute of Scrap Iron and Steel.)

12. U.S. Bureau of the Census. Steel Mill Products. Current Industrial Reports, 1977, pp. 18-21 (table 11).

13. U.S. Bureau of Mines. Iron and Steel Scrap. Mineral Industry Surveys, Monthly, 1957-77.

14. U.S. Department of Commerce. U.S. Imports for Consumption. Document FT246, 1977, p. 273.

APPENDIX A.--BACKGROUND

Stainless Steel Types and Chromium Content

Most grades of stainless steel have been classified by the American Iron and Steel Institute into three broad series--300, 400, and 200:

300 Series--The nonmagnetic 300 series (table A-1) is the most widely used form of stainless steel. The 18-8 alloys (referring to their chromium and nickel content, respectively) belong to this series. Besides chromium and nickel, other elements may be present in varying proportions, such as molybdenum in grades 316 and 317, and columbium in grade 347. This series of alloys is used in a great variety of applications in the construction industry, kitchen utensils, hospital equipment, chemical plants, refineries, and the aerospace industry.

400 Series--The 400 series (tables A-2 and A-3) is magnetic and consists of straight-chrome grades of stainless steel containing 10 to 27 percent chromium. This series of alloys contains various amounts of minor additions but little or no nickel. Some grades are ferritic (very low carbon), while others are martensitic. This series has a variety of uses, such as for decorative purposes, cutlery, automobile mufflers, and heat exchangers. Type 409 stainless steel is used exclusively for automobile catalytic convertor shells; its production is exceeded only by the all-purpose nickel-chromium 304 grades.

200 Series--The less common 200 series (table A-1) is nonmagnetic. In this series, manganese is partially substituted for nickel in order to retain the austenitic structure, resulting in a composition containing 3.6 percent nickel, 16 to 20 percent chromium, and 5 to 10 percent manganese.

Annual stainless steel production by AISI number can be found in Metal Statistics (2). By multiplying the median chromium composition shown in tables A-1, A-2, and A-3 by production in a given year, the average chromium composition is calculated to be 16.7 percent in both 1977 and 1957. This compares favorably with a 1974 value of 16.4 percent used in a chromium study for the National Materials Advisory Board (7, p. 129). The average value of 16.7 percent chromium in stainless steel was used throughout this study.

Although there are a large variety of stainless steel types, in any one year only about five of them account for about two-thirds of total production, as shown in table A-4.

TABLE A-1. - Chemical compositions of wrought chromium-nickel austenitic stainless steels

(Not hardenable by thermal treatment) (6)

SAE number[1]	Chemical composition limits, percent								AISI type number[1]
	C max.	Mn max.	Si max.	P max.	S max.	Cr range	Ni range	Other elements	
30201	0.15	5.5-7.5	1.00	0.060	0.030	16.00-18.00	3.50-5.0	N, 0.25 max.	201
30202	.15	7.5-10.00	1.00	.060	.030	17.00-19.00	4.00-6.00	N, 0.25 max.	202
30301	.15	2.00	1.00	.045	.030	16.00-18.00	6.00-8.00	-	301
30302	.15	2.00	1.00	.045	.030	17.00-19.00	8.00-10.00	-	302
30302B	.15	2.00	2.00-3.00	.045	.030	17.00-19.00	8.00-10.00	-	302B
30303	.15	2.00	1.00	.20	0.15 min.	17.00-19.00	8.00-10.00	Zr or Mo, 0.60 max.[2]	303
30303Se	.15	2.00	1.00	.20	.06	17.00-19.00	8.00-10.00	Se, 0.15 min.	303Se
30304	.08	2.00	1.00	.045	.030	18.00-20.00	8.00-12.00	-	304
30304L	.03	2.00	1.00	.045	.030	18.00-20.00	8.00-12.00	-	304L
30305	.12	2.00	1.00	.045	.030	17.00-19.00	10.00-13.00	-	305
30308	.08	2.00	1.00	.045	.030	19.00-21.00	10.00-12.00	-	308
30309	.20	2.00	1.00	.045	.030	22.00-24.00	12.00-15.00	-	309
30309S	.08	2.00	1.00	.045	.030	22.00-24.00	12.00-15.00	-	309S
30310	.25	2.00	1.50	.045	.030	24.00-26.00	19.00-22.00	-	310
30310S	.08	2.00	1.50	.045	.030	24.00-26.00	19.00-22.00	-	310S
30314	.25	2.00	1.50-3.00	.045	.030	23.00-26.00	19.00-22.00	-	314
30316	.08	2.00	1.00	.045	.030	16.00-18.00	10.00-14.00	Mo, 2.00-3.00	316
30316L[3]	.03	2.00	1.00	.045	.030	16.00-18.00	10.00-14.00	Mo, 2.00-3.00	316L
30317	.08	2.00	1.00	.045	.030	18.00-20.00	11.00-15.00	Mo, 3.00-4.00	317
30321[4]	.08	2.00	1.00	.045	.030	17.00-19.00	9.00-12.00	Ti, 5 X C min.	321
30330	.15	2.00	[5]1.50	.045	.04	14.00-17.00	33.0 -37.0	-	-
30347	.08	2.00	1.00	.045	.030	17.00-19.00	9.00-13.00	Cb-Ta, 10 X C min.	347
30348	.08	2.00	1.00	.045	.030	17.00-19.00	9.00-13.00	Cb-Ta, 10 X C min.; Ta, 0.10 max.	348

[1]The suffixes with grade numbers denote: B--2.00-3.00 silicon range; Se--a free-machining steel with selenium addition; L--extra low-carbon grade; S--lower carbon grade.

[2]At producer's option; reported only when intentionally added.

[3]10.0-15.0 Ni permitted for tubular products.

[4]9.0-13.0 Ni permitted for tubular products.

[5]To minimize carbon or nitrogen pick-up, 0.75-1.50 Si is recommended for high-temperature application involving carbon or nitrogen atmosphere.

TABLE A-2. - Chemical compositions of wrought martensitic chromium stainless steels

(Hardenable by thermal treatment) (6)

SAE number[1]	Chemical composition limits, percent								AISI type number[1]
	C max.	Mn max.	Si max.	P max.	S max.	Cr range	Ni range	Other elements	
51403	0.15	1.00	0.50	0.040	0.030	11.50-13.00	-	-	403
51410	.15	1.00	1.00	.040	.030	11.50-13.50	-	-	410
51414	.15	1.00	1.00	.040	.030	11.50-13.50	1.25-2.50	-	414
51416	.15	1.25	1.00	.06	0.15 min.	12.00-14.00	-	Zr or Mo, 0.60 max.[2]	-
51416Se	.15	1.25	1.00	.06	.06	12.00-14.00	-	Se, 0.15 min.	416Se
51420	Over 0.15	1.00	1.00	.040	.030	12.00-14.00	-	-	420
51420F	0.30-0.40	1.25	1.00	.06	0.15 min.	12.00-14.00	-	Zr or Mo, 0.60 max.[2]	-
51420F Se	0.30-0.40	1.25	1.00	.06	.06	12.00-14.00	-	Se, 0.15 min.	-
51531	.20	1.00	1.00	.040	.030	15.00-17.00	1.25-2.50	-	431
51440A	0.60-0.75	1.00	1.00	.040	.030	16.00-18.00	-	Mo, 0.75 max.	440A
51440B	0.75-0.95	1.00	1.00	.040	.030	16.00-18.00	-	Mo, 0.75 max.	440B
51440C	0.95-1.20	1.00	1.00	.040	.030	16.00-18.00	-	Mo, 0.75 max.	440C
51440F	0.95-1.20	1.25	1.00	.06	0.15 min.	16.00-18.00	-	Zr or Mo, 0.75 max.[2]	-
51440F Se	0.95-1.20	1.25	1.00	.06	.06	16.00-18.00	-	Se, 0.15 min.	-
51501	Over 0.10	1.00	1.00	.040	.030	4.00-6.00	-	Mo, 0.40-0.65	501

[1]Suffixes A, B and C denote differing carbon ranges for the same grade; F--a free-machining steel; Se--a free-machining steel with selenium addition.

[2]At producer's option; reported only when intentionally added.

TABLE A-3. - Chemical compositions of wrought ferritic chromium stainless steels

(Not hardenable by heat treatment) (6)

SAE number[1]	Chemical composition limits, percent								AISI type number[1]
	C max.	Mn max.	Si max.	P max.	S max.	Cr range	Ni range	Other elements	
51405[2]	0.08	1.00	1.00	0.040	0.030	11.50-14.50	-	Al, 0.10-0.30	405
51409	.08	1.00	1.00	.045	.045	10.50-11.75	0.50 max.	Ti, 6 X C or 0.75 max.	-
51430	.12	1.00	1.00	.040	.030	14.00-18.00	-	-	430
51430F	.12	1.25	1.00	.06	0.15 min.	14.00-18.00	-	Zr or Mo, 0.60 max.[3]	430F
51430F Se	.12	1.25	1.00	.06	.06	14.00-18.00	-	Se, 0.15 min.	430F Se
51434	.12	0.30-0.90	.50	.040	.030	16.00 min.	-	Mo, 0.75-1.25	-
51436	.12	0.30-0.90	.50	.040	.030	16.00 min.	-	Mo, 0.75-1.25; Cb, 0.25-0.75	-
51442	.20	1.00	1.00	.04	.035	18.00-23.00	-	-	-
51446	.20	1.50	1.00	.04	.030	23.00-27.00	-	N, 0.25 max.	446
51502	.10	1.00	1.00	.04	.030	4.00-6.00	-	Mo, 0.40-0.65	502

[1] Suffix F--denotes a free-machining steel; Se--denotes a free-machining steel with selenium addition.
[2] Essentially non-hardenable by heat treatment.
[3] At producer's option; reported only when intentionally added.

TABLE A-4. - Major types of stainless steel produced (thousand tons)

Type	1957	1967	1977
301	Neg	108	183
302 and 302B	163	Neg	Neg
304	144	523	[1]674
316 and 316L	63	104	144
409	Neg	Neg	[2]211
410	49	55	Neg
430	247	135	94
Subtotal	666	925	1,306
Other types, including heat resisting	378	525	560
Total	1,044	1,450	1,866
Five largest types as percent of total	64	64	70

Neg indicates type was not among the 5 largest types produced that year.
[1]Includes 304L.
[2]Data from American Iron and Steel Institute directly.

Source: American Iron and Steel Institute, as reported in Metal Statistics (2).

Scrap Classifications

Scrap is classified according to two criteria: chemical composition (including cleanliness) and physical form.

Scrap is priced according to its metal value as seen from the user's standpoint. Therefore, care is normally taken not to mix incompatible grades, such as those with and without molybdenum. On the other hand, no attention is paid to alloying elements (carbon, zirconium, or titanium) that are automatically controlled in the melting process.

For the purpose of international trade, various categories of stainless and heat-resisting alloy scrap are officially recognized, based on their chemistry; these are listed in table A-5. Domestic trade proceeds on a case-by-case basis, with all the specifics taken into consideration (physical properties, volume, appropriate location).

From the physical appearance standpoint, scrap can be classified into three categories (in decreasing order of available tonnage): light scrap, turnings and borings, and solids. Turnings may be shipped in bulk, or they may be crushed, blended, and even briquetted for ease of handling.

TABLE A-5. - Specifications for stainless steel and heat-resisting alloy scrap

Obole (95) Ferro-Nickel-Chrome Iron shall consist of alloys containing:

Chrome minimum	12 percent
Nickel minimum	12 percent
Copper maximum	.50 percent

Free of other foreign elements. Material shall be sold on basis of description and analysis. This category excludes all stainless steel grades which are covered elsewhere.

Pekoe (97) Chrome-Nickel-Manganese shall be of the following analysis:

Chrome	16-19 percent
Nickel	3.5-6 percent
Manganese	5.5-10 percent

Material to be free of harmful contaminants and be prepared to consumer's specifications

Sabot (98) 18-8 Stainless Steel shall consist of clean scrap containing:

Nickel minimum	7 percent
Chromium minimum	16 percent
Molybdenum maximum	.50 percent
Copper maximum	.50 percent
Phosphorus maximum	.045 percent
Sulphur maximum	.03 percent

Otherwise free of harmful contaminants. Material to be prepared to individual consumer's specifications.

Taffy (99) Stainless Steel Castings. Submit analysis, size of pieces, and physical description.

Ultra (100) 18-8 Stainless Steel Turnings. Machine shop grade for direct mill delivery shall contain:

Nickel minimum	7 percent
Chromium minimum	16 percent

Must be free of all non-ferrous metals, non-metallics, excessive iron, oil, and harmful contaminants.

Ultra Crush (101) Short or Crushed Stainless Steel Turnings shall conform chemically to machine shop grade specifications.

Rusten (102) 11-14 Percent Straight Chrome Stainless shall contain:

Chrome	11-14 percent
Phosphorus maximum	.03 percent
Sulphur maximum	.03 percent
Nickel maximum	.50 percent

Otherwise free of harmful contaminants. Material to be prepared to individual consumer's specifications.

Rusthirty (103) 14-18 Percent Straight Chrome Stainless shall contain.

Chrome	14-18 percent
Phosphorus maximum	.03 percent
Sulphur maximum	.03 percent
Nickel maximum	.50 percent

Otherwise free of harmful contaminants. Material to be prepared to individual consumer's specifications.

Source: Institute of Scrap Iron and Steel, Inc. (3).

Industry Sectors

Recyclers

Recyclers upgrade and sell a wide variety of metallic materials. In 1977 about 417,000 tons annually of stainless steel and heat-resisting alloy scrap was sold to melters. The size of a recycling company ranges from individual operators to large public companies with international subsidiaries or associated counterparts. In addition, recyclers handle nearly all of the scrap imports and exports.

Neither prompt industrial scrap nor obsolete scrap normally goes directly from the sources (for example, machine shop for new scrap, consumer for old scrap) to the final user (melter or export). One or more middlemen perform essential economic and technical tasks in collecting, shipping, blending, sorting, processing, and certifying all sorts of scrap items. Each may act as a scrap collector, broker, dealer, agent, trader, or integrated processor, depending on the particular contract and the extent of his financial and physical resources. This report considers all these activities as aspects of recycling.

Few recyclers are equipped to melt scrap. Those who are usually prepare master alloys of certified analysis for foundry use. The normal scrap preparation methods are confined to physical preparation (such as sorting, blending, and crushing of turnings) and occasional chemical analyses. A more detailed description of stainless steel and heat-resisting alloy scrap preparation and contamination problems is given in Bureau of Mines Information Circular 8781 (5).

Steel Service Centers

Steel service centers are retailers of steel products. Even those that belong to a subsidiary of a domestic melter usually buy steel from several sources. They sell to a broad range of customers who typically cannot justify buying the minimum-order sizes required by the mills.

In the process of cutting to desired dimensions, slitting, or burning plates, steel service centers generate an average of less than 1 percent scrap. The only operation that may generate an appreciable quantity of scrap on a percentage basis is plate burning; however, by nesting orders and making the best use of the plate area, steel service centers are able to limit scrap losses to 5 to 10 percent versus an average 15 percent if the customer does it himself.

Based on discussions with recyclers, the scrap generated by steel service centers is generally not returned directly to the producing mill. Rather it goes through recyclers before being exported or shipped to a particular melter.

Fabricators and Maintenance Shops

As used in this report, the term "fabricators and maintenance shops" applies to all firms involved in the transformation of finished stainless steel shapes into finished industrial or consumer goods. A wide variety of process operations generate scrap as a byproduct of fabricating plate, bar, rod, wire, sheet, and strip products; these operations include flame cutting, turning, lathes and automatic screw machines, precision drilling, reaming, boring, wet and dry grinding, stamping, forging, and extrusion.

APPENDIX B.--PROMPT INDUSTRIAL SCRAP GENERATION RATES

Table B-1 shows estimated prompt industrial scrap generation for 1957, 1967 and 1977 to range from 17 to 20 percent of apparent domestic consumption of stainless steel mill products. Table B-1 was developed from the following information:

1. Consumption of stainless steel mill products is found in table 1 for 1977. In addition, consumption of stainless steel mill products and of stainless steel in manufactured goods is found in table 5 for 1967 and in appendix C for 1957.

2. Prompt industrial scrap for 1977 is calculated in table 2.

3. Prompt industrial scrap for 1957 and 1967 is calculated by the difference between stainless steel in manufactured goods and stainless steel mill products consumed.

TABLE B-1. - Prompt industrial scrap generation for selected years

Item	1957	1967	1977
Apparent domestic consumption, thousand tons:			
Stainless steel mill products..........................	620	871	1,226
Stainless steel contained in manufactured goods.........	496	713	1,013
Estimated prompt industrial scrap generated..thousand tons	124	158	213
Prompt industrial scrap generation as a proportion of apparent domestic consumption of stainless steel mill products...percent	20	18	17
Average calculated yields in manufacturing goods from stainless steel mill products.................do...	80	82	83

Sources: Reference 1 for domestic shipments and reference 14 for net imports, which together represent apparent domestic consumption (see equation 12). All other values are Arthur D. Little, Inc., estimates.

APPENDIX C.--STAINLESS STEEL CONSUMPTION FOR MANUFACTURED GOODS IN 1957

As for the year 1967, the amount of stainless steel entering manufactured goods is calculated starting with the data in table C-1, showing the apparent domestic consumption of steel mill products. Table C-2 shows the distribution of stainless steel mill products consumed by selected market classification. Table C-3 shows the calculation for the quantity of stainless steel entering manufactured goods. In addition, the percent distribution of stainless steel consumed is shown by market classification which is used in developing table 6.

TABLE C-1. - Apparent domestic consumption of stainless steel mill products in 1957 (tons)

Market classifications	Semi-finished products	Wire products	Plates	Bars	Pipes and tubes	Sheet and strip	Total
Steel for converting and processing......	16,462	7,042	153	1,827	988	25,970	52,442
Forgings (not elsewhere classified)......	10,026	0	553	4,392	0	43	15,014
Industrial fasteners......................	12	4,354	0	2,487	0	1,340	8,193
Steel service centers and distributors...	11,389	10,563	20,597	44,188	4,327	115,220	206,284
Construction, including maintenance......	310	92	1,586	1,173	1,848	2,753	7,762
Contractors' products....................	186	420	87	756	294	12,478	14,221
Automotive...............................	9	494	23	3,257	30	102,490	106,303
Rail transportation......................	1	49	411	168	23	1,335	1,987
Shipbuilding and marine equipment........	0	240	513	1,013	47	529	2,342
Aircraft.................................	2,242	800	375	14,477	171	7,750	25,815
Oil and gas drilling.....................	59	111	8	504	0	130	812
Mining, quarrying and lumbering..........	15	34	125	74	0	274	522
Agricultural.............................	0	7	186	79	1	348	621
Machinery, industrial equipment and tools	1,221	5,572	5,061	15,736	2,381	20,928	50,899
Electrical machinery and equipment.......	137	619	592	8,605	32	3,406	13,391
Appliances, utensils, and cutlery........	0	1,066	142	1,394	18	31,990	34,610
Other domestic and commercial equipment..	11	492	199	805	61	12,580	14,148
Containers, packaging and shipping materials.............................	0	11	12	36	0	1,680	1,739
Ordnance and other military..............	15	17	1,071	356	77	868	2,404
Export (reporting companies only)........	461	130	424	787	556	23,913	26,271
Nonclassified shipments..................	1,838	0	6,673	6,852	16,996	1,616	33,975
Total domestic shipments............	44,394	32,113	38,791	108,966	27,850	367,641	619,755
Net imports.........................	0	0	0	0	0	0	0
Apparent domestic consumption.......	44,394	32,113	38,791	108,966	27,850	367,641	619,755

Sources: Domestic Shipments from AISI (1).
Net Imports from Department of Commerce (14).

TABLE C-2. - Adjusted distribution of stainless steel mill products by market classification in 1957 (tons)

Market classifications	Semi-finished products	Wire prod-ucts	Plates	Bars	Pipes and tubes	Sheet and strip	Total
Steel for converting and processing......	0	0	0	0	0	0	0
Forgings (not elsewhere classified)......	0	0	2,051	9,053	0	82	11,186
Industrial fasteners.....................	0	10,175	0	5,126	0	2,565	17,866
Steel service centers and distributors...	0	0	0	0	0	0	0
Construction, including maintenance......	0	215	5,882	2,418	10,807	5,271	24,592
Contractors' products....................	0	981	323	1,558	1,719	23,889	28,471
Automotive...............................	0	1,154	85	6,713	175	196,215	204,343
Rail transportation......................	0	115	1,524	346	134	2,556	4,675
Shipbuilding and marine equipment........	0	561	1,903	2,088	275	1,013	5,839
Aircraft.................................	0	1,870	1,391	29,840	1,000	14,837	48,938
Oil and gas drilling.....................	0	259	30	1,039	0	249	1,577
Mining, quarrying and lumbering..........	0	79	464	153	0	525	1,220
Agricultural.............................	0	16	690	163	6	666	1,541
Machinery, industrial equipment and tools	0	13,021	18,769	32,435	13,923	40,066	118,215
Electrical machinery and equipment.......	0	1,447	2,195	17,737	187	6,521	28,087
Appliances, utensils, and cutlery........	0	2,491	527	2,873	105	61,244	67,241
Other domestic and commercial equipment..	0	1,150	738	1,659	357	24,084	27,988
Containers, packaging and shipping materials............................	0	26	45	74	0	3,216	3,361
Ordnance and other military..............	0	40	3,972	734	450	1,662	6,857
Export (reporting companies only)........	0	0	0	0	0	0	0
Nonclassified shipments..................	0	0	0	0	0	0	0
Total..............................	0	33,600	40,587	114,010	29,139	384,661	601,997

TABLE C-3. - Adjusted percent distribution of stainless steel in manufactured goods by market classification in 1957 (tons)

Market classifications	Apparent domestic consumption, net tons	Adjusted domestic consumption, net tons	Prompt industrial scrap, net tons	Manufactured goods, net tons	Manufactured goods distribution, percent
Steel for converting and processing..........	52,442	0	0	0	0.0
Forgings (not elsewhere classified)..........	15,014	11,186	3,939	7,247	1.46
Industrial fasteners.........................	8,193	17,866	3,388	14,478	2.92
Steel service centers and distributors.......	206,284	0	0	0	0.0
Construction, including maintenance..........	7,762	24,592	3,611	20,981	4.23
Contractors' products........................	14,221	28,471	3,928	24,543	4.95
Automotive...................................	106,303	204,343	27,358	176,985	35.69
Rail transportation..........................	1,987	4,675	711	3,964	0.80
Shipbuilding and marine equipment............	2,342	5,839	1,331	4,508	0.91
Aircraft.....................................	25,815	48,938	14,287	34,651	6.99
Oil and gas drilling.........................	812	1,577	477	1,100	0.22
Mining, quarrying and lumbering..............	522	1,220	204	1,016	0.20
Agricultural.................................	621	1,541	254	1,287	0.26
Machinery, industrial equipment and tools....	50,899	118,215	23,492	94,723	19.10
Electrical machinery and equipment...........	13,391	28,087	8,403	19,684	3.97
Appliances, utensils, and cutlery............	34,610	67,241	9,144	58,097	11.71
Other domestic and commercial equipment......	14,148	27,988	3,936	24,052	4.85
Containers, packaging and shipping materials.	1,739	3,361	441	2,920	0.59
Ordnance and other military..................	2,404	6,857	1,146	5,711	1.15
Export (reporting companies only)............	26,271	0	0	0	0.0
Nonclassified shipments......................	33,975	0	0	0	0.0
Net imports..................................	0	0	0	0	0.0
Total....................................	619,755	601,997	[1]106,050	495,947	100.00

[1]Excludes prompt industrial scrap from conversion of semifinished products to finished steel mill products.

Sources: Table C-1 and Arthur D. Little, Inc., estimates.

APPENDIX D.--AVERAGE AGE OF OBSOLETE GOODS

About 648,000 tons of obsolete scrap was generated in 1977 (table 7). The average year (t) in which goods were manufactured that appeared as obsolete scrap in 1977 can be calculated, recognizing that the average yield (Y_{av}) from stainless steel mill products to manufactured goods is about 81 percent between 1957 and 1967 (appendix B). Thus, apparent domestic consumption (D_t) in the year (t) was about 800,000 tons of stainless steel mill products (648/0.81). Substituting $D_t = 800$ into equation 12 and solving, we find T = 64.3; thus, the average year (t) in which the goods containing stainless steel were manufactured is about 1964.

APPENDIX E.--OBSOLETE AND PROMPT INDUSTRIAL SCRAP COLLECTED

Stainless steel scrap data for 1977 of interest to this study were published by the Bureau of Mines in the May 1978 Mineral Industry Surveys of Iron and Steel Scrap (13). Companies reporting scrap shipments are "manufacturers of pig iron and steel ingots and castings," which are labeled as "Melters" in this study. Receipts of scrap by melters from "brokers, dealers, and other outside sources" reported by the Bureau of Mines totaled 424,000 tons in 1977. These receipts are thought to be largely purchased scrap according to the Bureau of Mines staff, and thus are included in the category of prompt industrial and obsolete scrap. The Bureau of Mines also reports receipts of stainless steel scrap "from other own company plants" as well as shipments by melters, which are not considered new supply. These receipts roughly balance reported shipments, with each amounting to about 10 to 15 percent of receipts from brokers, dealers, etc. Receipts and shipments are largely intercompany transfers of scrap between steel mills. Since scrap generated within steel mills is not considered in the scope of this study, it has been excluded from the estimates. In short, prompt industrial and obsolete scrap collection is estimated to be 424,000 tons in 1977.

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